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IMPACT OF ADVANCED MAINTENANCE DATA AND TASK ORIENTED TRAINING --ETC(U)
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AIR FORCE HUMAN RESOURCES LABORATORY

IMPACT OF ADVANCED MAINTENANCE DATA AND TASK ORIENTED TRAINING TECHNOLOGIES ON MAINTENANCE, PERSONNEL, AND TRAINING SYSTEMS

Prepared for
Department of Defense

By

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ADVANCED SYSTEMS DIVISION
Wright-Patterson Air Force Base, Ohio 45433

September 1978

Approved for public release; distribution unlimited.

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

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This final report was submitted by Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio 45433, in partial response to 23 June 1977 Secretary of Defense Memorandum, under project 1710, with HQ Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235.

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This technical report has been reviewed and is approved for publication.

GORDON A. ECKSTRAND, Director
Advanced Systems Division

RONALD W. TERRY, Colonel, USAF
Commander

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18. SUPPLEMENTARY NOTES

This report is in the form of a "white paper," which together with its executive summary (AFHRL-TR-78-24) has been prepared in partial response to the 23 June 1977 Office of the Secretary of Defense Memorandum, subject: "Management Review of Maintenance Training and Performance Aids." The memorandum was prepared as a result of a formal management review meeting held on 1 through 3 February 1977. Two major conclusions of that meeting

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

life cycle costs	head/book trade off	job performance aids (JPA)	costs of ownership of hardware
job and task analyses	aptitude tests	technical data presentation	technical training objectives
technical training	personnel selection	criterion referenced tests	vocational education objectives
maintenance training	human subsystems	maintenance effectiveness	symbolic substitute job tests
job oriented training	human factors measures	job task performance tests	human factors in life cycle costs

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report and its executive summary (AFHRL-TR-78-24) concern the impact of improved maintenance guidance and information (IMG&I), as well as task oriented training (TOT) technologies on DOD maintenance, personnel and training systems. The IMG&I considered include fully proceduralized job performance aid (FPJPA) technology for both non-troubleshooting (non-TS) and troubleshooting (TS) tasks; the Army "New Look" for non-TS tasks; and for TS tasks only: the traditional and enriched FORECAST aid, traditional and enriched logic tree troubleshooting aid (LTTA), and traditional and Air Force symbolic integrated maintenance system (SIMS), as well as a newer form of SIMS called the functionally oriented maintenance manuals (FOMM).

However, the technologies or concepts, whose effectiveness is supported by comparative hard data, include

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Item 18 Continued:

are addressed in the memo, namely, (a) the *need* to implement an existing technology base in job performance aid manuals, and (b) the *need* for more effort on integrated *technical data*, training, and personnel support systems that are based on analysis of the job task requirements. The first requirement was assigned to the Navy and fulfilled by NPRDC TR 77-33, "Symposium Proceedings: Invitational Conference on Status of Job Performance Aids Technology," May 1977.

This report and its executive summary, address the second requirement which specifically addresses the requirement for the preparation of such a paper "on the applicability of job aids and the impact on the personnel and training systems." Included in this requirement is a discussion of "the applicability of job aids, training or both to enhance *military jobs proficiency*," as well as the identification of service and DOD policies that restrict payoffs in this area. (Industrial approaches to task analysis, job aids, training and personnel utilization are also discussed.)

The author was designated as chairman of a committee which included Dr. Robert Blanchard of the Navy Personnel Research and Development Center, San Diego, CA; Mr. John K. Klesch of the Army Training Development Institute, Ft Eustis VA; and Mr. Harry Maragides of Headquarters, Marine Corps, Washington, DC. After the first draft of the required paper was prepared a committee meeting was held at Headquarters, Air Force Human Resources Laboratory (AFHRL), Brooks AFB TX, on 13 December 1977. (Although Mr. Klesch was unable to attend, the other committee members, as well as LTC Roger Grossel of Department of Defense – OASD (MRA&L)WR and Mr. Robert Johnson of the Advanced Systems Division (AFHRL), Wright-Patterson AFB OH, were present.) The comments of this meeting resulted in some reorganization of the first draft, as well as the requirement for the executive summary.

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fully proceduralized maintenance technical data
research and development proposals
fully proceduralized job performance aids (FPJPA)
training/job performance aid trade-off
measurement and evaluation maintenance training
measurement and evaluation vocational education
symbolic integrated maintenance system (SIMS)
FORECAST
job guide manuals (JGM)
job performance manuals (JPM)
behavioral analyses of tasks (BAT)
personnel systems for maintenance
fully proceduralized troubleshooting aids (FPTA)
curriculum development (technical training)
measurement and evaluation technical training
measurement and evaluation electronics training
improved maintenance guidance information (IMG&I)
symbolic integrated maintenance manuals (SIMMS)
Army "New Look"

Item 20 Continued:

only: the FPJPA, FORECAST aid, enriched LTTA, and AF SIMS. These hard data indicate that quality implementation of any of these technologies (or concepts) will result in more efficient performance of maintenance tasks than the use of the traditional maintenance manual (TMM). (In this regard, there are no hard data which indicate that the FOMM is more effective than the AF SIMS.) But, by far the most dramatic reductions of the life cycle cost (LCC) of hardware ownership can be realized by the quality integrated application of three of these types of IMG&I with TOT; i.e., FPJPA, FORECAST TS Aid, and enriched LTTA. Of these, the FPJPA has the most potential.

Much of the executive summary and the body of the white paper are similar in organization and content. However, the white paper contains a more complete treatment of human, hardware, and software problems, and policies which are impeding, or will impede, the implementation of these money saving technologies. Although dramatic LCC reductions can be effected by the quality implementation of IMG&I and TOT technologies, such implementations require greater dollar investments in maintenance guidance documents and in training than the implementing establishments are accustomed to spend. But additional money is not enough–quality implementations require "know how." A mechanism must be developed which makes efficient and effective use of the "know how" of the developers of the technologies, and makes them responsible and accountable for their early implementations. In this regard, most past implementations have "watered down" such technologies.

Of special interest to executives and managers are two tables which consolidate the important attributes of various IMG&I types and TMM; a figure which summarizes the results of many DOD TOT studies; and a flow diagram which portrays a model for maximizing benefits of FPJPA, SIMS, and TOT technologies.

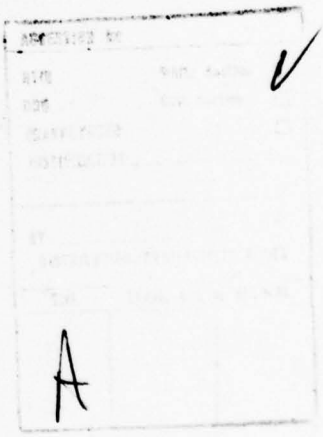
The white paper also contains a number of appendices which summarize most of the DOD studies which have produced hard data concerning various IMG&I. Other appendices describe and discuss TMM and the various IMG&I as well as military and industrial applications of IMG&I and TOT.

PREFACE

This report represents a protion of the exploratory development program of the Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio.

The preparation of this report was documented under task 171004, Job Performance Aids for Air Force Maintenance Technicians. The task is part of project 1710, Training for Advanced Air Force Systems. The effort represented by this paper was identified as work unit, 17100427. Mr. Robert Johnson was task scientist. Dr. Ross L. Morgan was project scientist.

The author wishes to express his appreciation for the cooperation and inputs of the other members of the interservice committee designated for this effort. They include Dr. Robert Blanchard of the Navy Personnel Research and Development Center, San Diego, CA; Mr. John K. Klesch of the Army Training Development Institute, Ft Eustis, VA; and Mr. Harry Maragides of Headquarters, Marine Corps, Washington, DC. The comments of LTC Roger Grossel of the Department of Defense – OASD(MRA&L)WR and Mr. Robert Johnson of the Advanced Systems Division of AFHRL are also greatly appreciated.



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I. INTRODUCTION

This report, together with its executive summary (AFRHL-TR-78-24, Foley, 1978), was prepared in response to the 23 June 1977 Office of the Secretary of Defense Memorandum, subject: "Management Review of Maintenance Training and Performance Aids." The memorandum was prepared as a result of a formal management review meeting held on 1–3 February 1977.

Two major conclusions of that meeting are addressed in the memo, namely, (a) the *need* to implement an existing technology base in job performance aid manuals and (b) the *need* for more effort on integrated *technical data*, training, and personnel support systems that are based on analysis of the job task requirements. The first need was at least partially satisfied by a recently published report of the Navy Personnel Research and Development Center concerning the status of job performance aid (JPA) technology (NPRDC TR 77-33, Booher, 1977). This paper concerns the second need and specifically addresses the requirement of the memorandum for the preparation of a paper "on the applicability of job aids and the impact on the personnel and training systems," (although the appendices also contain a large amount of materials relative to the status of JPA technology). Included in the requirement for this paper is a discussion of "the applicability of job aids, training or both to enhance *military job proficiency*." A large part of the primary missions of the Army and Marines, and almost all of the Navy and Air Force primary missions, are concerned with the development, operation and maintenance of complex hardware systems; therefore, the requirement for the enhancement of proficiency in the performance of operator and maintenance jobs is especially critical. Traditionally the military services have given a great deal more attention to the proficiency of operator task performance than to the proficiency of maintenance task performance. But this emphasis is shifting. The life cycle costs (LCCs) of such hardware systems are extremely high and continue to rise. Important factors contributing to LCC are high maintenance personnel costs and the high cost of spare parts, as well as the unnecessary usage of spare parts.

A large portion of high maintenance personnel costs in the military services is contributed by the cost associated with first enlistment personnel. Because of consistently low reenlistment rates of maintenance personnel, a large portion of DOD maintenance tasks must be performed by relatively inexperienced first enlistment personnel. The costs for supporting all first enlistment personnel are currently estimated at $15,000 per person per year, or $60,000 for a four-year enlistment. But generally, the effective period of on-the-job performance of maintenance tasks for such personnel is relatively short (as low as 1 year in some cases), making the actual work year labor costs of useful work from first enlistment personnel extremely high (as high as $60,000 for one year of useful work).

At least two important factors contribute to this generally short, on-the-job performance time of first enlistment maintenance personnel. The entry training programs, both formal and on-the-job, for many maintenance personnel skill codes are or have been long. (But in spite of such lengthy training programs, there is substantial evidence that maintenance tasks generally are not performed with high efficiency, either by first enlistment personnel or by personnel with longer on-the-job experience.) A second factor is the current "early out" policies of the services. If the escalation of DOD maintenance costs is to be controlled, ways must be found to increase the on-the-job utilization of first enlistment personnel, as well as to increase the efficiency with which all maintenance tasks are performed.

This report is concerned with attaining these objectives by the proper selection and implementation of several available concepts and/or technologies. *One* purpose is to describe these concepts and

technologies which include the job task performance test (JTPT), task oriented training (TOT), and several types of maintenance directions and/or information – such as the fully proceduralized job performance aid (FPJPA), logic tree troubleshooting aid (LTTA), symbolic integrated maintenance system (SIMS), and functionally oriented maintenance manual (FOMM). A *second* purpose is to discuss the potential of each concept, or technology, for reducing each cost factor. A *third* purpose is to present a general implementation model or plan, which integrates compatible technologies for maximum cost savings. A *fourth* is to discuss approaches to task analysis, job aids, training and personnel utilization being applied by industry. The *final* and most important *purpose* is to identify current practices, policies, and problems which impede or prevent the implementation of such concepts and technologies. (Since the materials or discussions concerning the first, second, and fourth purposes are rather voluminous, they are only summarized in the body of this report. Where applicable, more extensive treatments have been included as appendices.)

II. IMPROVING THE PERSONNEL/HARDWARE INTERFACE

The proper application and use of several technologies and/or concepts of improved maintenance guidance and information (IMG&I) could improve the performance of maintenance tasks. In addition, the concurrent and integrated application of a few of these maintenance guidance and information technologies (together with the task oriented training technology) would greatly reduce the entry training time for first enlistment maintenance personnel.

Improved Maintenance Guidance and Information Technologies and/or Concepts

Table 1 identifies the name and source of each of these technologies and/or concepts together with a brief description of each. Most of these technologies are aimed at improving the performance of troubleshooting (TS) tasks. *Only two* are aimed at improving the performance of non-troubleshooting (non-TS) tasks, such as checkout tasks; align, adjust, and calibrate tasks; and install, remove, and replace tasks. Table 2 indicates these and other attributes for the technologies and/or concepts listed in Table 1. In addition, appendices A and B provide more complete descriptive information as well as some historical information concerning these technologies and concepts.

Table 2 also indicates that some of these concepts are effective with highly trained and/or experienced personnel, while others will support the performance of personnel with limited experience and/or training. The effectiveness of a few of these concepts is supported by hard data, while that of others is not. Where comparative hard data have been gathered for a concept, they have indicated that the use of the concept (or technology) by highly trained and experienced personnel would result in more efficient performance of the categories of maintenance covered (non-TS or TS tasks or both) than the use of the traditional maintenance manual (TMM). The key word in this statement is "use." An improved IMG&I concept or technology must be used during the performance of tasks to be effective.

The only concepts whose effectiveness is supported by hard data are FPJPA, FORECAST, enriched LTTA, and Air Force SIMS, plus the TMM. Most of the studies providing these hard data are summarized in the various appendices of this report. Column 1 of Table 3 indicates each of these concepts, Column 2 indicates the applicable references for each concept, and Column 3 indicates the appendices in which these references are summarized. All of the studies indicated have produced some hard data. Column 4 indicates those which have produced substantial comparative hard data concerning the various concepts. Indepth study and analyses of these data indicate that some IMG&I technologies are more effective than others for high aptitude personnel who are highly trained and experienced but that only FPJPA and FORECAST have proven effectiveness with medium aptitude personnel with limited training. The various relationships are summarized in the following paragraphs.

Table 1. Name and Brief Descriptive Information Concerning IMG&I, and TMM

Short Title or Acronym	Title or Descriptive Statement	Sample	Source	Other Name	Remarks
FPJPA	Fully Proceduralized Job Performance Aid (FPJPA) Technology	AFHRL-TR-73-43 (Joyce et al., 1973a, 1973b 1973c)	1. AFHRL Exploratory Development 2. Air Force Project PIMO[a] 3. AFHRL Advanced Development 4. Vietnamization 5. NADC Advanced Development[b]	1. Air Force "Job Guide Manuals (JGM)" (Non-TS Tasks) 2. Army—"Job Performance Manuals (JPM)" (Non-TS Tasks) 3. Air Force—"Fully Proceduralized Troubleshooting Aids (FPTSA)"	1. A few JGM reflect FPJPA technology 2. JPM specified in Draft Mil-M-632XX(TM) 3. FPTSA developed for research purposes only
Army "New Look"		Mil-M-63037(TM)	Army-Materiel Development and Readiness Command (DARCOM)	N/A	DARCOM has replaced JPM with "New Look"
Traditional FORECAST	Code Name for an Army TOT research project	HumRRO-TR-66-23 (Shriver & Trexler, 1966)	For Army by Human Resources Research Organization (HumRRO)	Cue Response Sets	
Enriched FORECAST		Draft Mil-M-362XX(TM) - Parts I & II	U.S. Army Human Engineering Laboratory	N/A	Similar to traditional with some pictorial locators added
Traditional LTTA	Logic Tree Troubleshooting Aids (LTTA)		A traditional category—used in some TMM during WW II	Troubleshooting Trees	
Army LTTA		Mil-M-63037(TM) and Mil-M-63038	Army DARCOM	N/A	LTTA with varying amounts of enrichment
Enriched LTTA		C-141 Organizational level TS TM (Also, some Army LTTA for the tank turret and wheeled vehicles)	Air Force Logistics Command (AFLC) Also – Johnson, et al., 1977	N/A	For AFHRL Study (Potter and Thomas, 1976) 1. Organizational level developed by Westinghouse 2. Intermediate level by Lockheed 3. LTTA with controlled enrichment
Traditional SIMS	Symbolic Integrated Maintenance System (SIMS)	HumRRO-TR-66-23 (Shriver & Trexler, 1966) also Mil-M-24100A (Ships)	Disputed, however, Mil-M-24100A was developed by Navy	Symbolic Integrated Maintenance Manual (SIMMS or SIMM)	1. Heart of system Maintenance Dependency Chart (MDC) 2. Also blocked schematics and blocked information
AF SIMS		Mil-M-38799	1. Air Force Project PIMO 2. Vietnamization 3. AFLC	N/A	1. MDC with step-by-step procedures in standard language and pictorial locators 2. Less complex symbols than traditional MDC 3. Keyed schematics and keyed information
FOMM	Functionally Oriented Maintenance Manuals (FOMM)	Mil-M-24100B	Mil-M-24100B developed by Navy. (This FOMM specification supersedes the traditional SIMS, Mil-M-24100A).	N/A	1. More sophisticated and complex symbols than traditional MDC 2. Alternate columns on MDC in color 3. Keyed schematics and keyed information
TMM	Traditional Maintenance Manual	N/A		Air Force Technical Order (TO)	See AFHRL-TR-75-82 (Foley, 1975) for description of categories

[a]Presentation of Information for Maintenance and Operations (PIMO).
[b]Naval Air Development Command (NADC).

Table 2. **Important Attributes of IMG&I and TMM**

Technology and/or Concept	Non-TS Tasks	TS Tasks	Development Requires TI&A	Step-by-step Directions in Standard Language	Keyed Pictorial Locators of Functional Units	Use Requires High Level of Test Equipment Proficiency	Effectiveness with Varing Degrees of Training and Experience: Minimally Trained and Experienced	Effectiveness with Varing Degrees of Training and Experience: Highly Trained and/or Experienced	Aptitude Requirements	Hard Data Supporting Effectiveness	Key Documents Presenting Hard Data	Specification and/or Guidance Documents	Remarks
FPJPA	X	X	Yes	Yes	Yes	Yes	Yes	Yes	High and/or Medium	Yes	Serendipity Inc, 1969 Potter & Thomas, 1976 Elliott & Joyce, 1968 Elliott, 1967 Mullen & Joyce, 1974 Shriver & Foley, 1975 Shriver, 1975 Theisen et al., 1978	AFHRL-TR-73-42 (I),(II),(III), (Joyce et al., 1973a, 1973b, 1973c)	Data indicate minimum training requirements for entry personnel
Army "New Look"	X	Optional	Optional	No	Some	Yes	Possibly	Presumed	High and possibly medium	No	None	Mil-M-63037(TM)	Specification does not require standard content for directions or pictorial locators.
Traditional FORECAST		X	Yes	No	No	Yes	Yes	Yes	High and/or medium	Yes	Shriver et al., 1964	None	Data indicate greatly reduced training requirements for entry personnel.
Enriched FORECAST	*	X	Yes	Some	Yes	Yes	Yes	Yes	High and/or medium	Yes		Draft Mil-M-632XX(TM) Part I*	Enriched by adding pictorial locators.
Traditional LTTA		X	No	No	No	Yes	No	Presumed	High only	No	None	None	
Army LTTA		X	Optional	No	Optional	Yes	Possibly	Presumed	High and possibly medium	No	None	Mil-M-63037(TM) and Mil-M-63038	
Enriched LTTA		X	Yes	Some	Yes	Yes	Possibly	Yes	High and possibly medium	Yes	Potter & Thomas, 1976	Being Developed	Inexperienced subjects had completed long entry training.
Traditional SIMS	**	X	No	No	No	Yes	No	Presumed	High Only	No	None	Mil-M-24100A (Ships)	MDC symbols for traditional SIMS more complex than for AF SIMS
AF SIMS		X	No	Yes in MDC	Yes in MDC	Yes	No	Yes	High Only	Yes	Serendipity Inc 1969 (Hard data concern PIMO SIMS)	Mil-M-38799	AF SIMS enriched by pictorial locators
FOMM	**	X	No	No	No	Yes	No	Presumed	High Only	No	None	Mil-M-24100B	MDC symbols for FOMM more complex than for either traditional or AF SIMS
TMM	Some	X	No	No	No	Yes	No	Least Effective	High Only	Yes	All of the above referenced documents	Format only	All hard data have indicated least effective for supporting maintenance

*Draft Mil-M-632XX (TM), Part I, provides FPJPA for non-TS tasks.

**Directions for some non-TS tasks are provided. These directions are similar to those provided by TMM, therefore, not part of concept.

Table 3. **References and Appendices Containing Hard Data**

Concept	Author Reference	Summarized in Appendix	Scope of Comparison
FPJPA	Serendipity, 1969	D, E	FPJPA (non-TS) vs. TMM
	Potter & Thomas, 1976	D, G	FPJPA (TS) vs. LTTA vs. TMM
	Elliott & Joyce, 1968 Elliott, 1967a	D	FPJPA vs. TMM
	Mullen & Joyce, 1974	D	N/A
	Shriver & Foley, 1975 Shriver, 1975	D, F	N/A
	Theisen et al., 1978	H	N/A
FORECAST	Shriver et al., 1964	C	FORECAST vs. TMM
Enriched LTTA	Potter & Thomas, 1976	D, G	LTTA vs. FPJPA(TS) vs TMM
AF SIMS	Serendipity, 1969	D	AF SIMS vs. TMM

Comparative Effectiveness of Various IMG&I for Highly Trained and/or Experienced Personnel

The comparative hard data produced by the various studies, referenced in Table 2, indicate the following effectiveness relationships for IMG&I when used by highly trained and/or experienced personnel.

1. For non-TS tasks:
   a. FPJPA $\gg$[1] TMM
2. For TS tasks:
   a. FPJPA $>$[2] Enriched LTTA $\gg$ TMM
   b. Traditional FORECAST $\gg$ TMM
   c. AF SIMS $\gg$ TMM

The use of any of the indicated improved technologies in lieu of the TMM would improve the efficiency of highly trained and experienced maintenance personnel. This improved efficiency would be reflected in reduced spare parts usage, shortened cross-training on unfamiliar hardware, and perhaps, increased numbers of maintenance tasks performed.

IMG&I and Potential for Reducing Maintenance Personnel Costs

If LCC is to be greatly reduced, those technologies that maximize the utilization time and efficiency of first enlistment personnel must be fully exploited. This objective requires the application of those technologies which are not only effective for improving maintenance efficiency but also have potential for reducing entry training requirements. Table 2 indicates that only three technologies, for which hard data are available, meet both of these criteria, i.e., FPJPA, traditional FORECAST and, by projection, enriched FORECAST. The hard data indicate the following effectiveness relationships:

1. For non-TS tasks:
   a. FPJPA $\gg$ TMM

[1] $\gg$ Much more effective than.

[2] $>$ More effective than.

2. For TS tasks:
   a. FPJPA ⟫ TMM
   b. Traditional FORECAST ⟫ TMM

(Although there are hard data concerning LTTA, the subjects used had no experience but had received long initial formal training.)

"Head/Book" Trade-Off Analysis

Currently, there are no hard data which indicate the relative effectiveness between FPJPA and FORECAST aids for reducing entry training requirements. However, analyses of each technology or concept, based on consideration of the developmental requirements (including task identification and analyses (TI&A) products, as well as on content and format requirements, indicate that the FPJPA technology requires the user to store and recall less guidance and information for task performance than the other technologies or concepts–thus reducing the task training requirements for entry, as well as for experienced, personnel. Expressed in other terms, the FPJPA technology relegates more maintenance guidance and information to the "book" and less to the "head" than do other technologies or concepts. Compared on the basis of like analyses, the comparative potential of the applicable technologies for reducing entry training time and for increasing the maintenance efficiency of first enlistment personnel is indicated as follows:

1. For non-TS tasks:
   a. FPJPA ⟫ New Look
2. For TS tasks:
   a. FPJPA ⟫ Enriched FORECAST $\approx$[3] Enriched LTTA

(Enriched rather than traditional FORECAST aids are included in these statements. Enriched FORECAST aids relegate more to the "book" than do the traditional variety.)

Based on the results of these analyses, Table 4 indicates combinations of technologies which would be effective for reduction of initial training time for first enlistment personnel. These are listed in the order of their potential for reducing initial training time as well as for increasing maintenance efficiency.

Table 4. **Effectiveness of Three Combinations of IMG&I Technologies for Reducing Initial Training Time**

Combination	Non-TS Tasks	TS Tasks	Order of Effectiveness
1	FPJPA	FPJPA	1
2	FPJPA	Enriched FORECAST	2.5
3	FPJPA	Enriched LTTA	2.5

The indicated relative effectiveness for these combinations can be expressed as a formula; i.e.,

$$1 \gg 2 \approx 3$$

Enriched LTTA is defined as a TS aid of the same degree of enrichment as those produced for the C-141 aircraft, which were used for organizational level TS in the Air Force Human Resources Laboratory (AFHRL) study reported by Potter and Thomas (1976), and Potter, Hubbert, Landolfi, Rice, and Kearns

[3] $\approx$ Of equivalent effectiveness.

(1976a, 1976b). At the request of the Air Force Logistics Command (AFLC), AFHRL is now developing a draft specification which should insure the development of LTTA of consistently high quality from hardware to hardware. Such consistency will make the indicated training trade-off for a cluster of hardware possible. The current specifications for developing LTTA do not ensure such consistency. "New Look" aids for non-TS tasks are not included in Table 4 because the current specifications for developing these aids have a similar consistency weakness. In addition, there are no hard data available that attest to their effectiveness for supporting the performance of such maintenance tasks.

Integrated Implementation of FPJPA and TOT Technologies

Figure 1 provides a summary of results of key research efforts concerning the effectiveness of TOT technology. Six of the 11 TOT efforts indicated were supported by the Army, three by the Air Force, and two by the Navy. Most of these 11 efforts concern training for maintenance jobs supported by the TMM. Since the TMM provides much less guidance and in most cases less information than any of the combinations shown in Table 4, the maintainer must compensate for the TMM deficiencies. Of course, in this case a relatively longer and, therefore, more costly TOT program is requied than when more effective maintenance guidance and information carrry most of the guidance load.

This "head/book" trade-off problem has been addressed by a few reserachers. The Navy report by Theisen, Elliott, and Fishburne (1978), which is summarized in Appendix H, and the Air Force report by Mullen and Joyce (1974) concern integrated applications of FPJPA and TOT technologies, and the report by Shriver, Fink, and Trexler (1964) concerns the integrated application of FORECAST and TOT technologies. Both integrations have proven effective; however, the FPJPA/TOT integration will usually result in shorter training time. Since the thrust of this report is the maximization of on-the-job time for first enlistment maintenance personnel, the discussions that follow will consider the potential impact of FPJPA/TOT integrations (Combination 1 shown in Table 4) on DOD personnel and training systems. But most of what is said would also apply to an integration of FPJPA-FORECAST Combination 2 (Table 4) and TOT. However, the TOT would be appreciably longer because less of the guidance and information in FORECAST has been relegated to the book.

Considering the transitory nature of maintenance personnel, as well as their training, logic would dictate that maximum utilization be made of the "book" when determining the head/book trade-off. What is put in the "book" remains in the book, the quality and quantity of its contents do not deteriorate with time, all copies of the book are identical, and the content of the book will never deteriorate from lack of use. On the other hand, what is relegated to the "head," or training, may never be fully and accurately assimilated by many individual maintainers, and the amount of assimilation will vary from individual to individual. Once an individual has attained the desired task proficiency, such proficiency will deteriorate rather rapidly with lack of use. In addition, the individual's stay in DOD in most cases is relatively short, so whatever proficiency he has is soon lost, and the training cycle must be repeated for his replacement, ad infinitum.

The current state-of-the-art for IMG&I/TOT reflected by Theisen et al. (1978), Mullen and Joyce (1974), and Shriver et al. (1964) attests to the feasibility of such trade-offs. In addition, the AFHRL draft FPJPA specification and the handbooks provide some guidance for FPJPA/TOT trade-off. Substantial DOD maintenance gains can be realized by the implementation of the current state-of-the-art. (However the ground rules for such trade-offs could probably be greatly refined by further R&D. The accomplishment of this important area of R&D has been delayed for several years by the failure of appropriate DOD training establishments to support it. Hopefully, one outcome of the current R&D program of the Navy Personnel Research and Development Center (NPRDC) will be a refinement of IMG&I/TOT trade-off ground rules.)

Use of Test Equipment. An often neglected key factor, concerning head/book trade-off and the performance of maintenance tasks, is the requirement for high proficiency in use of test equipment. To

The purpose of this figure is to identify the types of controlled studies supporting IMG&I and/or TOT, to give the general flavor of their results and to direct the interested reader to available summaries and lists of references on job oriented training, technical data, and performance measurement.

The armed services have conducted at least 11 controlled studies concerning the effectiveness of job oriented training programs for maintenance. The experimental job oriented training programs developed for these studies have been aimed at several types of job situations. Some have been structured to train new military enlisted personnel to perform maintennace jobs involving a number of hardware systems. Other programs were aimed at existing single system jobs. For both these types or programs, the existing job situations were accepted without change. For at least two studies, the job situations were simplified for the experimental subject by modified information or directions for performing job tasks and the TOT program for each was developed with the objective of training the subjects to perform the tasks of the simplified job.

The effectiveness of each of these 11 experimental job oriented training programs was compared under controlled conditions with the existing theory centered training programs used to train similar personnel. A summary of most of these studies together with a list of reports was made by Foley (1967). Further information concerning the more recent studies can be obtained from Elliott (1967a), Elliott and Joyce (1968), Chalupsky and Kopf (1967), Pieper et al., (1970), Pickering and Anderson (1966), Steinemann and Hooprich (1967), Steinemann et al. (1967), Van Matre and Steineman (1966), Mullen and Joyce (1974), Shriver et al. (1964) and Theisen et al. (1978).

The last two documents report hard data which attest to the feasibility of and training gains from IMG&I/TOT trade-offs. The report by Shriver et al., pertains to FORECAST TS aids/TOT trade-offs applied to a small cluster of electronic hardware, whereas the report by Theisen et al. pertains to a FPJPA/TOT trade-off for one hardware item. The Mullen and Joyce report describes the demonstration of another FPJPA/TOT trade-off but contains no comparative hard data.

An indepth review of all these studies indicates that (a) job oriented training subjects could perform the tasks of their jobs with much less on-the-job training (OJT) than the control subjects, (b) medium and some low aptitude subjects were more successful in job oriented training programs than in traditional training programs, (c) job oriented training courses were shorter than conventional courses, and (d) when the jobs were modified with improved job instructions and information, the TOT was much shorter.

An indirect source of insight as to the questionable effectiveness of theory-based maintenance training programs is found in research on performance measurement. The student measurement programs in all theory-based training programs are heavily weighted with paper-and-pencil tests of theory and job knowledge. A student usually learns well those things on which he is tested. Foley's summary (1974) of the available performance measurement research literature indicates that the *relationship* between the test subjects' ability to actually perform the tasks of maintenance jobs and their scores obtained on theory or job knowledge tests is very low. Likewise, the correlation is low between school marks and measures of job performance. A strong inference can be draw from these. The only way most personnel learn to perform job tasks is by practicing those job tasks properly. Learning job tasks by practice is what TOT is all about.

Figure 1. **Research efforts supporting IMG&I/TOT trade-off.**

date, most IMG&I developments have assigned the use of all test equipment functions to the "head" rather than the book. Under such conditions, the TOT must contain sufficient practice of test equipment functions to ensure "over learning." But, this is not enough, there must be periodic performance tests in the

field to ensure that maintenance personnel sustain this necessary high proficiency. The model JTPT battery reported by Shriver and Foley (1974a) provides a sub-battery of JTPT for test equipment. Model task oriented programmed instruction packages (i.e., task oriented training) are available which provide "hands on" practice in the use of general electronic test equipment (see Scott & Joyce, 1975a through 1975l). *Since such general test equipment are used across many hardware clusters, a most cost effective action for improving the quality of maintenance even with TMM would be a DOD-wide program for improving test equipment proficiency. Such a program would require only modifications and expansions of the available model TOT packages and JTPT battery.*

Maximum Job Utilization of First Enlistment Personnel

Attention is directed to the portion of Table 5 concerning entry into the first enlistment. This portion of the table summarizes both the training gains and maintenance gains which can be expected from a quality implementation of the FPJPA and TOT technologies. The gains would, without a doubt, result in tremendous reductions in LCC of hardware ownership.

Requirement for High Quality Backup Support

It is estimated, based on hard data, that entry first enlistment personnel having received high quality TOT can accurately isolate 90 to 95 percent of hardware troubles using FPJPA (see Table 5, column 5, item 3, for first enlistment personnel). It should be emphasized that, based on available information, this level of accuracy greatly exceeds the present performance of most DOD maintainers. This superior TS performance alone would reduce spare parts usage and secondary damage of hardware by reducing the current great reliance on excess remove and replace actions for fault correction.

But even though a quality integrated implementation of FPJPA and TOT technologies would greatly improve the current efficiency of maintenance, appropriate steps should be taken to insure the efficient solution of the 5 to 10 percent of faults that might elude isolation by FPJPA. The lower portion of Table 5 concerns the development of a cadre of backup personnel with the ability to efficiently isolate such elusive faults, as well as to perform other functions which will be discussed later.

III. VERSATILE MODEL FOR MAXIMIZING BENEFITS OF FPJPA AND TOT TECHNOLOGIES

Figure 2 appears *as the foldout at the end of this report.* The flow chart displayed in this illustration represents a modification of a chart developed by Dr. Robert Blanchard as part of his planning for the current research program of the NPRDC, San Diego, California (Blanchard & Laabs, 1978). The illustration also contains information displayed in Table 5. Most of the information found in that table is inserted at the appropriate places in the flow chart. Much of the chart has been designed to be self-explanatory, but some of its key blocks require discussion. To facilitate the use of the chart in the discussions that follow, each functional block on the chart has been numbered.

The chart (Figure 2) is divided into two parts by a heavy dashed line between Blocks 11 and 12. The portion of the chart to the left of this dashed line is designated as "First Term" functions. As used in this chart, "First Term" is applied to personnel who are in their first enlistment, and who have not extended their enlistments to take advantage of the broadbased training represented by Block 12. The portion of the chart to the right of this dashed line contains "Second Term" functions. "Second Term" is applied to first enlistment personnel who have extended their enlistment to take the broadbased training.

In many respects this is an extremely versatile model. For example, it can be applied to one hardware system or a cluster of hardware. However, to obtain the maintenance and training gains indicated, there are five extremely firm requirements:

1. *Quality FPJPAs must be developed for all the hardware in the cluster under consideration. Such aids must reflect the key characteristics and requirements of the FPJPA technology as discussed in*

Table 5. **Proposed Maintenance TO Categories, Types of Training, and Expected Gains from Full Implementation**

Enlistment	Categories of Job Aids	Type of Training	Training Gains Expected	Maintenance Gains Expected
First (Entry)	1 FPJPA (Non-TS Tasks) 2 FPJPA (TS Tasks)	Short job-oriented training with supervised practice on 1 Use of FPJPA 2 Use of Hand Tools. 3 Use of Test Equipment 4 Safety practices	1 Length of initial training reduced by as much as percent. 2 Resulting in fewer people requiring training. Average, as well as, high aptitudes could be trained. 4 Shorter personnel build up time required for national emergencies. 5 Reduction in initial OJT and job cross training. 6 Reduction or elimination of formal special and supplemental training.	1 Such personnel job ready at end of formal training. 2 More effective performance at non-TS tasks. 3 More effective performance of TS Tasks – estimate such personnel can isolate 90 to 95 percent of possible troubles. 4 More months on job due to shorter training time, thus fewer personnel in the Air Force. 5 Minimum of cross training to unfamiliar equipments (provided FPJPA available on unfamiliar equipments). 6 More effective utilization of maintenance personnel during peck and/or emergency. 7 Fewer unsolved maintenance problems referred to depot ∴ reduction in depot maintenance. 8 Fewer space parts consumed. 9 Less paper work generated. 10 Less secondary damage from unnecessary maintenance actions.
Extended first as well as *second* and beyond SIMS or FOMM	1 FPJPA (Non-TS Tasks) 2 FPJPA (Most TS Tasks) For Unusual TS Tasks: 3 MDC with pictorial locators 4 Blocked schematics 5 Keyed information 6 Pictorials with locators grids. 7 Aircraft wiring diagrams. 8 IPB 9 Preservation, Shipping and Storage Info.	Broadbased training developing ability for solving and correcting unusual maintenance problems	1 More effective training for backup personnel. 2 Fewer people requiring long, broadbased training.	1 A larger number of highly effective backup maintenance personnel for performing unusual and difficult maintenance tasks. 2 Fewer unsolved maintenance problems referred to depot ∴ reduction in depot maintenance.

Appendix B. These include TI&A: standard language and keyed pictorials for maintenance instructions; appropriate format for the maintenance environment; as well as "hands on" validation of the effectiveness of the product by the contractor; "hands on" verification of the effectiveness of the product by the purchasing DOD agency; and warranty of the product by the contractor.

2. *To be effective, these quality FPJPAs must be used by each maintainer while he is performing his job tasks.*

3. *Quality TOT programs must be developed which support and complement the FPJPA for the cluster of hardware under consideration. The fit between the FPJPA and the TOT is extremely critical for efficient job performance of first term personnel.*

4. *The advancement of all first term maintenance personnel both in skill and pay levels must be accomplished on the basis of demonstrated ability to perform job tasks. This requires the elimination of all paper-and-pencil theory and job knowledge tests from first term advancement requirements.* (Scores from such paper-and-pencil tests have little relationship to ability to perform maintenance tasks (Foley, 1974).)

5. *After initial training, each first term maintainer must perform both non-TS and TS maintenance tasks on a full time basis for at least one year using FPJPA (Block 6).* This is an extremely important requirement for the cost effective utilization of first enlistment personnel. Here is where the maintainer "pays for his or her keep"; demonstrates his potential usefulness to DOD, including the demonstration of good work habits and of ability to use his hands; and thus earns the privilege of obtaining advanced training (Block 12).

Key Features of the Model

Current Aptitude Tests (Block 1). Current DOD aptitude tests have been designed to select people who will do well in current entry maintenance training programs. For example, many current Air Force entry maintenance training programs require people with aptitudes of 80 percentile and above to successfully complete current academically oriented entry training programs. A large number of such personnel do not aspire to make maintenance a career, accounting in part for low reenlistment rates as well as "early outs." However, both TOT and FPJPA research have indicated that most middle or medium aptitude, as well as high aptitude personnel, as measured by current aptitude tests, can successfully complete TOT training and can perform maintenance tasks adequately. So for the present, the current aptitude tests can be used for selecting entry maintenance personnel. One simply has to adjust the aptitude cutoff score.

Short Entry TOT (Block 3). This block represents integrated applications of the FPJPA and TOT technologies. In a short summary presentation; such as this, it is not feasible to discuss all of ramifications and possibilities for such integrated applications, but a few of the key and unique characteristics are mentioned.

1. *The meshing of the content of the FPJPA for the cluster of hardware under consideration and the content of the TOT represented by this block is an absolutely necessary ingredient for such applications. This meshing requires precise task identification for all hardware selected for the cluster, followed by a very careful trade-off as to which tasks or parts of tasks for each hardware will be relegated to TOT and/or FPJPA. To achieve this, the same trade-off ground rules must be applied for each hardware in the cluster (see Joyce, Chenzoff, Mulligan, & Mallory, 1973a, 1973b, 1973c).*

2. *TOT packages (for initial training) must be developed which require the trainee to perform "hands on" practice of key tasks using FPJPA on whichever hardware of the cluster is available for training purposes.* Since the trainee will receive his instructions for performing such "hands on" practice, much of the TOT package will be a training management document identifying the tasks to be practiced. Such a TOT package will also provide instructions for practice on those activities which have been assigned to training; such as use of test equipment. Once the trainee has learned to perform tasks using one hardware he will be able to perform tasks on each of the other hardware in the cluster with a minimum of cross-training. Such cross-training packages must be developed as required, covering only those activities not included in the FPJPA nor in the initial package.

3. *The physical location of the entry TOT programs can either be centralized in one location or decentralized: i.e., at or near the initial job assignment of each trainee.* If quality FPJPA and quality TOT packages to match become available, on-site job entry training similar to that utilized by the Office Products Division of IBM (as discussed later in this report) may become the most cost effective route for many DOD maintenance situations. *(In fact, the Army is now planning to conduct on-site initial training, but without the quality FPJPA discussed here.)*

4. *The proposed TOT would practically force first term maintainers to use FPJPA to perform their tasks because that will be the only way these people will have been trained to do their job tasks.* This would reduce one of the current DOD maintenance problems, that of getting maintainers to use their maintenance instructions.

Job Task Performance Test (JTPT) Battery (Block 4). JTPT battery, similar to the model described by Shriver and Foley (1974a), should be developed for each cluster of hardware. The use of such tests is another absolutely necessary ingredient for maximizing the utilization of first term maintainers. The objective of the proposed TOT programs is to teach people to perform maintenance tasks of a specific number of hardware items using FPJPA–the objective is not to teach people to pass paper-and-pencil theory and job knowledge tests. The only appropriate tests for insuring the achievement of such a task performance objective is the JTPT. There is nothing really new about the idea of using the JTPTs as training criteria. They were used extensively by the Navy and Air Force during and after World War II (Foley, 1977). What is new, is their refinement (Shriver & Foley, 1974a).

In addition to their worth for ensuring the task performance ability of entry personnel, the use of JTPT provides the basis for a great improvement of the DOD posture concerning several equal-employment-opportunity (EEO) rulings of the U.S. Supreme Court. (These rulings have indicated that the selection of employees, as well as their promotion should be based on ability to perform job tasks (Alluisi, 1977).) It is worth noting that the Office Products Division of IBM uses task performance tests as the sole criteria for successful completion of entry training and as prime criteria for all career advancement. (AFHRL has support work which has produced some graphic symbolic substitute tests of promising empirical validity (Shriver & Foley, 1974b). However, the technology for developing symbolics requires more refinement before such tests can be recommended for operational use.)

"Skill Level" Upgrade on First Job (Block 6). The award of a 4 skill level is provided after about 6 months on the first job. This skill level will indicate that the maintainer has demonstrated his ability to perform his job tasks and has demonstrated good work habits. The award of this 4 level could be made on the basis of a supervisor's evaluation. This is a proposed new skill level.

Career Evaluation and Selection for Broadbased Training (Blocks 7 through 12). The career evaluation envisioned for Block 7 would be based on three factors. The *first* (a go, no-go factor) would be a comprehensive JTPT battery which would ascertain that the maintainer could perform a wide range of maintenance tasks using FPJPA and that he had a high degree of expertise in the use of test equipments. The *second* factor would be a supervisor's rating. The *third* factor would be an aptitude test battery for the broadbased training. If the maintainer successfully completed this evaluation process, he would be awarded the 5 skill level and he would become eligible for an offer to extend his enlistment for broadbased training (Block 12).

Since the number of training spaces for such broadbased training would be limited, a successful completion of the career evaluation might not result in an immediate offer. The maintainer might have to continue working in the Block 10 status until there was an available opening. But whenever such an offer was made, it would be accompanied by an offer of a bonus. The amount of the bonus could vary with the needs of the services. Any 5 level individual who declined to extend his enlistment (and any individual who failed the Block 7 evaluation) would continue to work in a Block 10 status as indicated on the flow chart.

Potential Dollar Gains from Improved Utilization of First Term Personnel (Blocks 6 and 10). Consider those personnel that remain in the FPJPA mode for their entire first enlistment. An addition of the times shown in Blocks 6 and 10 indicates a total of from 3 to 3½ years of effective job time. Based on

the estimated total of $60,000 personnel cost for a 4-year first enlistment individual, mentioned earlier; 3 years of effective job time would cost DOD $20,000 per year. When compared to some individuals in the current job situation, from whom only one year of effective job time is realized, ($60,000 per man-year), this would be a saving of $40,000 per man. Applied only to 100 individuals, this would result in a $4,000,000 saving. Consider also the individual who, after 18 months, extends his enlistment for broadbased training (Block 12). Based again on the $60,000 figure for 4 years. DOD will have received 1 full year of productive labor for $22,500 before he extends. *And*, for his extended 4 years, DOD can expect 3 full years of effective job time at $20,000 per year. These manpower savings could result in more qualified maintenance people on the job without increasing the total number of personnel in DOD. *And*, these savings do not include those that can be expected from improved maintenance efficiency. The types of gains being considered are of the same magnitude as those realized when automobile manufacturers changed their mode of operation to production lines.

Improved Aptitude Tests (Block 8). The results of the JTPT batteries administered in Blocks 4 and 7 would provide a data bank for the development of an improved aptitude test battery. Since the new aptitude test battery would be standardized against measurements of ability to perform job tasks, the objective of TOT, the prediction of such a battery for the initial training and job success should be improved over current batteries. The use of aptitude tests based on ability to perform job tasks, as well as, the use of JTPT for determing training success would result in a great improvement of the DOD posture concerning the previously mentioned EEO rulings of the U.S. Supreme Court. The Office Products Division of IBM has developed and is using such an aptitude test battery, which has been validated against training success and field performance, as measured by job task performance (see Appendix K).

Second Term Training (Block 12). It is envisioned that there would be several such courses in each service, each course being aimed at an extensive cluster of hardware. Each such hardware cluster would probably reflect a limited number of vintages of hardware design. Selection for one of these courses would consider both the needs of the service and the desires of the individual. An individual could be selected for training for a cluster of hardware which does not match his initial assignment. The personnel selected for the broadbased training, indicated in Block 12, would have several advantages over those now receiving lengthy entry training. An important advantage is a well developed real-world frame of reference concerning maintenance. This will make broadbased training much more effective. Since only selected experienced people with a long term commitment would attend such a course, the motivation to learn should be high.

Such training programs to be effective would require extremely careful planning and execution. Each program should be based on a careful study and analysis of the expected job utilization of its graduates. As indicated in the task guidance display for Blocks 12 and 13, graduates would use FPJPA for most tasks. They would also be expected to use and have available several additional categories of maintenance guidance and information which include the unique SIMS or FOMM categories; i.e., maintenance dependency charts (MDC), blocked schematics, and keyed information. As a result, a large portion of each broadbased training program should include a large amount of "hands on" activity solving many difficult maintenance problems using these documents.

Utilization of Graduates of Second Term Training (Block 13). The graduate of one of these broadbased courses would truly be a generalist and could provide several valuable functions. They could provide backup for first term personnel assigned to hardware with FPJPA. They would also be expected to perform maintenance on hardware for which no FPJPA is available, including the performance of maintenance on transient aircraft.

A probably more effective and less costly scheme for utilizing some of these graduates and for providing at least part of the required backup capabilities would be a centralized maintenance information center, which could be called by telephone whenever a difficult problem is encountered. A highly trained expert, for each hardware system being maintained, would be assigned to such a center. Such a center could

reduce the number of highly trained backup personnel required in the field for all hardware. In cases where only a few items of a specific hardware have been procured by DOD, it could possibly be used as a substitute for costly maintenance instructions and special training. This concept was recommended in one of the early AFHRL job performance aid technical reports (Folley & Shettel, 1962). A modification of this concept is being used successfully by the Office Products Division of IBM.

Appropriate Utilization of SIMS anf FOMM (Blocks 12 and 13). An appropriate utilization of SIMS type data including FOMM is also indicated on the flow chart (Figure 2) in conjunction with Blocks 12 and 13. As mentioned previously hard data indicate that such aids improve the TS performance of highly trained and experienced personnel. Three versions of SIMS data are indicated on Table 2; i.e., traditional SIMS, Air Force SIMS and FOMM. The hard data concerning SIMS was gathered from the use of Air Force type of SIMS. Currently, there are no data which indicate that FOMM is more effective than Air Force SIMS.

There are only three categories of SIMS type aids which impact TS performance more than TMM and these are included in the list of nine guidance and information categories for experienced and highly trained personnel (see Figure 2, Blocks 12 and 13). They are the MDC, blocked schematics, and keyed information. Although the specifications cited in Table 2 for traditional SIMS and for FOMM provide for some step-by-step instructions for non-TS tasks, these instructions are of the traditional variety found in TMM. (FPJPA for non-TS tasks are, therefore, much more effective.)

The MDC is the heart of the SIMS TS concept; however, the human factors characteristics of the MDC vary greatly among the various versions of SIMS. An analysis of the characteristics displayed in Table 6 indicates that the Air Force type of SIMS is superior from a human factors point of view, containing some of the features of the FPJPA technology. The Air Force MDCs contains step-by-step checkout procedures in standard language and each component mentioned is keyed to a locator pictorial. In addition, the symbology used for indicating dependencies in Air Force MDCs is the least complex of those used for these aids.

When the checkout procedures of the MDC identify an out-of-tolerance condition, the chart provides a set of dependent functional units, the fault to be identified being within the set. That is, it gets the maintainer in the right ball park fast. (To be effective each set of dependencies must be complete.) From this point on, he must plot his own course of action making use of the hardware descriptions found in the block schematics and keyed information. It is during this "free wheeling" activity that the maintainer can make costly errors resulting in inefficient TS.

IV. CURRENT R&D EFFORTS

Currently, there are only two active R&D programs in DOD concerning IMG&I.

Navy R&D Program

The Navy is the only service which has consistently supported R&D concerning FPJPA/TOT trade-off. Starting in 1972, the Human Factors Engineering Division of the Naval Air Development Center (NADC) supported an effort that resulted in a controlled comparative study (Theisen et al., 1978) which produced hard data attesting to the feasibility and effectiveness of the FPJPA/TOT trade-off. Currently, the NPRDC at San Diego, California, has a new 3-year advanced development project which is aimed not only at refining the IMG&I/TOT trade-off, but more importantly at solving the personnel and training implementation problems. This project, No. Z0828PN entitled Job Performance Aid Test and Evaluation, should result in the necessary guidelines for optimum FPJPA/TOT trade-offs. Some contract efforts should be completed by late 1979.

Table 6. **Key Human Factors Characteristics of Three Versions of SIMS Type MDC**

Parts of Chart	Air Force SIMS Mil-M-38799	Traditional SIMS Mil-M-24100A (Ships)	FOMM Mil-M-24100B
X-Axis	1. Step-by-step checkout procedure 2. Standard language 3. Keyed pictorial locators for components mentioned	1. Step-by-step checkout procedure 2. *No* Standard language requirement 3. No pictorial locators	1. Step-by-step checkout procedure 2. No standard language requirement 3. No pictorial locators
Y-Axis	1. Functional units listed 2. Column for each functional unit 3. Keyed pictorial locator for each functional unit	1. Functional units listed 2. Column for each functional unit 3. No pictorial locators	1. Functional units listed 2. Column for each functional unit 3. Alternate columns in color 4. No pictorial locators
Body or Cells (Displays dependency sets made up of abstract symbols)	1. Lowest number of abstract symbols to be learned by user 2. Least complex dependency sets	1. More symbols to be learned than for AF SIMS 2. Dependency sets more complex than for AF SIMS	1. Largest number of symbols to be learned. 2. Most complex dependency sets

Current Air Force R&D

The Air Force supported the initial development work of the task identification and analysis (TI&A) technology which has been basic to the more recent developments of job effective IMG&I and TOT by the Army and Navy (Miller, 1953; Miller & Folley, 1951). Also, the Air Force conducted the first TOT study which started in 1953 (Foley, 1964) and supported most of the exploratory development and early advanced development of the FPJPA technology (see Appendix D). In addition, the Air Force conducted a preliminary, uncontrolled demonstration of FPJPA/TOT trade-off (Mullen & Joyce, 1974). However, the Air Force did not fund planned controlled comparative research concerning such trade-offs.

However, (as mentioned previously) the AFHRL, at the request of Air Force Logistics Command (AFLC), is now developing a specification under contract for TI&A. In addition, a specification for LTTA is being developed under the same contract. Some consideration is also being given to expand this same mix of IMG&I (JGM for non-TS tasks and LTTA for TS tasks) to the organizational maintenance of other hardware, as well as to intermediate maintenance. Such improved applications should greatly improve the efficiency of maintenance but will not set the stage for the maximum utilization of first enlistment personnel by effective FPJPA/TOT trade-off as indicated in Figure 2.

V. CURRENT IMPLEMENTATION ACTIVITIES

Army Implementation Activities

It will be recalled that the Army supported over half of the early R&D concerning TOT, including the important FORECAST effort which, also, produced the effective FORECAST TS aids discussed previously. And the Army is now in the forefront concerning implementation. The Army's Integrated Technical Documentation and Training (ITDT) Program is by far the boldest and most far reaching implementation action ever taken to exploit the benefits of IMG&I, TOT, and the IMG&I/TOT trade-off. This program already contains many of the aspects, displayed in Figure 2, for shortening of initial training of first enlistment personnel, as well as the decentralization of such training by providing TOT packages and by assigning the responsibility for initial training to operational units. This program is being institutionalized by the MIL-M-630XX series of specifications. As will be discussed later, these specifications require major modifications if the expected and necessary results of IMG&I and TOT technologies are to be achieved. However, they do provide the overall framework for more effective and efficient utilization of first enlistment personnel provided the necessary specification modifications are made and adequate enforcement mechanisms are developed and used. More details concerning Army implementation activities are found in *Appendix I*.

Navy Work Packages

The Navy Air Systems Command (NAVAIR) has developed the Mil-M-819XX(AS) series of specifications which include provisions for work packages that are a decided improvement, when compared with the TMM. Each such work package is designed to support the performance of one non-TS or TS maintenance task. A common aspect of each work package is a consolidated presentation of available information and guidance pertaining to a task; materials, which are normally dispersed throughout the TMM. Since each work package is task oriented, the FPJPA technology and the work package concept are compatible. Many work packages reflect, at least, the format aspects of the FPJPA technology. However, the specifications contain no firm requirements for applying the FPJPA technology–including TI&A. NAVAIR requires the development of work packages for all new systems. The work package concept certainly is an improvement over the TMM and provides the framework for a full implementation of the results of the recently completed NADC FPJPA/TOT trade-off R&D (Theisen et al., 1978).

Air Force Implementation of FPJPA Technology

As far as the Air Force implementation of the FPJPA technology is concerned, the technology, as developed, is based on TI&A and is applicable to both non-TS and TS tasks for both the organizational (O)

and intermediate (I) levels of maintenance. However, the implementations, to date, have concerned only non-TS tasks for the organizational maintenance of aircraft. Job Guide Manuals (JGM) for organizational maintenance in FPJPA format have been developed for the C-141, B-52, KC-135, F-106 (partial), F-5E, and the A-10 aircraft. They are being developed for the F-16 and are planned for the Advanced Medium STOL Transport (AMST) as well as for various other subsystems for the Aeronautical Systems Division (ASD) and Electronic Systems Division (ESD). Such JGM were also planned for the B-1. Of these JGM developments, those for the C-141 are the only manuals which reflect the TI&A aspects of the FPJPA technology. More details concerning the Air Force applications are found in Appendix J.

Industrial Implementation Efforts

Five industrial organizations have been identified for their advanced approaches to TI&A, IMG&I, training and/or personnel utilization: two steel corporations, Armco Corp. and U. S. Steel; Cleveland Engine Plant of Ford Motor Company; Office Products Division of IBM; and Bell System. These advanced industrial approaches are very similar to those presented and recommended for DOD implementation. All of these applications can be traced to human factors R&D supported by the military services. In general, the military services have been ahead of industry in human factors R&D for maintenance, but behind some industries in applications.

The Office Products Division of IBM has an impressive integrated system of personnel utilization. This integrated system has many of the characteristics of the proposed program, outlined in Figure 2, including effective IMG&I/TOT trade-offs; all training success and job advancement are based primarily on ability to perform job tasks as measured by the JTPT; personnel selection procedures have been validated against such tests; the responsibility for maintenance manual development, engineering changes, aptitude test development, formal training development and execution, field training packages development, and performance assessment center operation is under one directorate; and the actual selection, hiring, and initial training of maintenance personnel have been decentralized and are the responsibility of the line managers in the field. An important aspect of this IBM program for DOD executives and managers is that the program is operating and has been operating successfully for several years. Appendix K provides a more complete description of this IBM system of personnel utilization.

The Bell System uses TI&A extensively for solving operator and maintenance personnel and training problems. A reflection of the strong interest in TI&A by the Bell System is its sponsorship of a "Conference on Uses of Task Analysis in the Bell System," in October 1972. However, the Bell System approach does not generally include formal and precise trade-offs of TOT and IMG&I. The applications made by Bell Systems are for solving specific problems. Important ingredients for ongoing applications of the FPJPA technology by Bell System have been the development of an internal guide for the preparation of FPJPA and an accompanying training program for FPJPA developers. These efforts were accomplished under the auspices of the Bell Laboratories. With some modifications, this training is now one of the regular and popular courses given by Bell Laboratories at Piscatway, New Jersey, for managers, the idea being to greatly reduce or eliminate much costly training by using good job instructions. Another version of this training program is given by New England Bell at Marlborough, Massachusetts (see Appendix L for more detail).

The Armco and U. S. Steel IMG&I/TOT applications are very similar, both being originally applied to the maintenance of the electronic controls on their rolling mills. These two organizations turned to the IMG&I/TOT technologies after traditional training approaches resulted in expensive maintenance failures. Both organizations have now applied IMG&I to other maintenance problems. A description and discussion concerning the Armco experience are reported in an issue of Iron Age (Snodgrass, 1976). A summary of this Armco experience is provided in Appendix M. More recently, the Cleveland Engine Plant of the Ford Motor Company is having an IMG&I/TOT program developed for the maintenance of its programmed control production equipment.

VI. PROBLEMS AND POLICIES WHICH IMPEDE IMPLEMENTATION

General

1. DOD lacks a department-wide policy requiring that only those technologies and concepts whose effectiveness is supported by comparative hard data should be considered for implementation. Sales talk and "eye appeal" are unacceptable bases for expending large sums of operational money for untested concepts or proposed technologies even if they are innovative. The only concepts and technologies that should be implemented for operational purposes are those whose effectiveness for maintenance and/or training is supported by comparative hard data obtained from well designed and controlled tryouts.

2. Getting well developed and adequately tested technologies, such as FPJPA and TOT, institutionalized is a perennial problem, especially when a technology requires fundamental changes in long existing programs, procedures, and attitudes of entrenched establishments. The Advanced Systems Division of AFHRL has been involved in the implementation of several well developed and documented technologies, such as FPJPA and instructional systems design (ISD) including programmed instruction and job (task) oriented training. These experiences have indicated that it is extremely difficult to maintain the integrity of a technology during its so-called implementation. Operational organizations invariably attempt to implement a much "watered down" version of the technology and consequently obtain much "watered down" results. In some cases, only cosmetic changes to existing programs are reported as implementations. Currently, it requires years of persistent effort on the part of the research community to get a technology properly institutionalized. All of the current operational implementations of the FPJPA, the FORCAST, and TOT technologies have suffered or are suffering from this "watering down" phenomenon. Examples include most Air Force developments of so-called JGMs for organizational maintenance for existing and new weapons systems (Mil-M-38800, as well as Mil-M-83495), Army Developments of Integrated Technical Documentation and Training (ITDT) systems, and the Air Force TOT implementations, including BRIGHT SPARK and ABLE CHIEF.

3. A mechanism must be developed for the timely institutionalization of each promising new technology, which will ensure its integrity. A mechanism for the orderly implementation of technologies similar to that used for new weapons systems is recommended. Such a mechanism must make efficient and effective use of the "know how" of the developers of the technology and make them responsible and accountable for its implementation. A new technology should not be turned over to a using command for its operation until it is in place, "debugged" and operational – just as a new weapons system is not turned over to an operational command until it has been "debugged" and proven to be ready for operational use.

4. Although the proper implementation of quality TOT and FPJPA technologies will result in significant savings in overall maintenance labor costs and in substantial reductions in spare parts consumption, their implementation will require relatively large investments in quality maintenance guidance and information and in quality TOT programs, as well as, changes in personnel and training systems. Such necessary changes will require an integrated and concerted effort on the parts of the maintenance, technical data, training, personnel, and R&D establishments. All actions of the affected establishments must be aimed at maximizing the utilization and efficiency of first term maintenance personnel.

Personnel Establishments

1. The current DOD personnel systems for maintenance must be changed to better reflect and accommodate the various vintages of hardware and the great proliferation of hardware types in the present and future DOD inventories. The required improvements in utilization of first enlistment personnel will require changes, not merely cosmetic patches to the current maintenance personnel systems. However, such changes should be well planned and implemented in manageable increments so as not to disrupt the operations of the services. An effective mechanism must be established which gives primary consideration to the *needs*, not necessarily the currently expressed wants of the maintenance systems. The mechanism

must have the power to effect the necessary changes. In this regard most of the expressed wants of maintenance managers reflect long experience with traditional training and maintenance guidance. They have no frames of reference based on experience with IMG&I and TOT. As a result, they are unable to project their needs in terms of these unfamiliar technologies.

2. Large portions of current DOD maintenance personnel systems reflect a policy that all entry personnel identified for maintenance assignments should be treated as if most or all such personnel were going to make maintenance of military hardware a career. This policy has resulted in many long and expensive career oriented training programs for first enlistment personnel. DOD personnel policy should clearly indicate that DOD maintenance personnel should not be considered as, or treated as, career personnel until they have indicated their career intentions by reenlisting or by extending their first enlistments.

3. The use of operational functions of hardware subsystems as the primary basis for maintenance assignment codes is no longer a viable concept. In addition, the personnel system must be changed to reflect the fact that a major portion of DOD maintenance tasks must be performed by first term personnel. What changes should be made will depend on the types of training and/or maintenance guidance documents that are to be used. But any job code should reflect clusters of the same general vintage of hardware, as well as similar training and maintenance tasks guidance.

4. Maintenance personnel systems should support the maximum job utilization of first term personnel. This would require that advancement in "skill level" and pay during the first term of maintenance personnel would be based on ability to perform job tasks. (By first term personnel is meant all maintenance personnel in their first enlistment who have not extended their enlistment for advanced broadbased training – see Figure 2.) All paper-and-pencil job-knowledge and theory tests should be eliminated for these first term maintenance personnel.

5. To implement the model and to effect the savings described in Figure 2 will require the reclustering of hardware for maintenance assignment codes for first term maintainers to which the model is applied. This will probably require a new maintenance assignment code for each cluster of hardware to which the FPJPA/TOT trade-offs are applied. The number of hardware in a cluster should be manageable. For early applications, the maintenance of each cluster should require a large concentration of maintainers, and if possible, all hardware in the cluster should reflect a limited number of design vintages. Such reclustering is required because all FPJPA/TOT trade-offs must be based on the same trade-off ground rules, and the FPJPA for each hardware in the cluster must be of the same high quality.

6. The appropriate application of TOT and FPJPA would make the clustering of hardware systems a less difficult task. For example, all of the electronic subsystems without regard to their function for one major weapon system, or for several similar major weapon systems, could be placed in one assignment code. Such a clustering would be possible if FPJPA were provided for all hardware in each cluster and if all hardware in the cluster were of the same general vintage.

7. Currently many maintenance assignment codes not only cover large numbers of hardware subsystems but they are also responsible for the performance of both non-TS as well as TS tasks at both O and I levels of maintenance. The difficulty and complexity of O level tasks seem to be remaining fairly constant over hardware systems. However, I level tasks, especially TS tasks, which were extremely difficult in the past, are becoming very simple on some new hardware systems. Generally, non-TS tasks are less difficult to perform than TS tasks. In clustering tasks for maintenance assignment codes, both the O/I maintenance level dichotomy and the non-TS/TS task dichotomy should be given serious consideration as criteria for such clustering.

8. In further regard to the application of these dichotomies, the type of job performance aids development policy must be reflected. Currently the Air Force is supplying aids with some characteristics of the FPJPA technology for non-TS tasks at the O level of maintenance of new weapons, whereas for TS tasks for the same level, either symptom-cause charts or LTTAs with uncontrolled enrichment being

developed. For both non-TS and TS tasks at the I level of maintenance, TMMs are currently being produced. Under such conditions, a FPJPA/TOT trade-off would be only possible for non-TS tasks at the O level. (Of course, the easiest way to solve this problem is to develop FPJPA for all tasks at both levels of maintenance.)

9. Since the development of improved types of maintenance guidance is both the Air Force and the Army is being obtained for new weapons systems, clusters of tasks for each new weapons system should be considered as the prime basis for new maintenance assignment codes for such systems. If overall cost-effectiveness of maintenance is the objective, the type of guidance provided for all tasks included in any one maintenance assignment code must be of the same type.

10. The changes in maintenance documents and training, as well as the necessary restructure of personnel systems discussed in this report, would cause drastic changes in the content of many military and civilian positions in the maintenance, training, and technical data establishments. If either the pay or the status of already-in-place personnel is adversely affected by such changes, the necessary changes will never be truly effected. In fact, the status and pay of those people expected to implement the necessary changes should be enhanced. The DOD personnel establishments should follow the lead of a few industrial establishments who protect their already-in-place employees from the adversities resulting from change.

Technical Manual Establishments

1. It is emphasized that the realization of such gains, as indicated in Figure 2, requires that the integrity of advanced technologies be maintained during their implementation. It is absolutely necessary that their integrity be reflected in official specifications, guidance documents, policies, and well written work statements in contracts. In this regard, the current DOD official specifications and guidance concerning IMG&I technologies have deficiencies. For example, Mil-M-38800 concerning JGM reflects format aspects of the FPJPA technology, but not the important TI&A aspects. Although the FPJPA technology covers both non-TS and TS tasks for both I and O levels of maintenance, Mil-M-38800 is limited to only non-TS tasks for the O level maintenance of aircraft. A more recently developed Air Force specification, Mil-M-83495, (although limited to O level) covers both non-TS and TS tasks for all vehicles including aircraft. It, too, is only a format specification. It calls for JGM for non-TS tasks which greatly deviate from the standard language and locator pictorial requirements of the FPJPA technology. For TS tasks, the specification calls for Fault Isolation Manuals (FI) which are modeled after an Air Transport Association specification. Currently there are no comparative hard data available which would support the use of such FI in DOD maintenance establishments. However, AFLC has requested AFHRL assistance for correcting at least part of these shortcomings. Mil-M-38799 concerning Air Force type SIMS does not require TI&A. The Mil-M-630XX series, developed by Army DARCOM, provides for TI&A but not for important in-process reviews. In addition, the effectiveness of the types of IMG&I specified by the Mil-M-630XX series documents are not supported by comparative hard data.

2. To develop the quality of maintenance documents necessary to effect the overall maintenance improvements and reductions in maintenance labor costs, will require at least from 50 to 100 percent more money than the Maintenance Manual Establishments have been accustomed to spend for current maintenance guidance and information. The budget managers must realize that this is a one-time, front-end investment that must be made in order to obtain the desired system lifetime cost reductions. Whatever is lacking in the maintenance guidance documents must be supplied during every year of system life by more training, more support and test equipment, more spare parts, larger inventories of major hardware components, and more depot maintenance.

3. For maximum first enlistment utilization, based on current research findings, aids developed in accordance with the FPJPA technology are required for both non-TS and TS tasks for both O and I levels of maintenance. Such aids will be effective for both high and average aptitude personnel.

4. To be effective FORECAST aids for TS, developed in keeping with draft Mil-M-632XX, Part I, will require more initial TOT than FPJPA for TS. Such FORECAST aids are probably less effective for

early quality performance of first-term personnel but no comparative hard data are available to support this assumption. No personnel aptitude data are available concerning thses aids.

5. LTTA with controlled enrichment such as those used in the recently completed AFHRL advanced development effort (Potter & Thomas, 1976) will improve the TS performance of experienced and conventionally trained personnel. Such aids will require more initial TOT than FPJPA for TS and they will probably do little for the early quality performance of first term personnel. The effectiveness of such aids has only been tested on high aptitude personnel.

6. Maintenance guidance documents with uncontrolled content or untested results, no matter how great their eye appeal, should not be developed or purchases for use by first-enlistment personnel. Examples include symptom-cause charts for TS, LTTA with uncontrolled enrichment, and "new look" documents.

7. The MDC is the "heart" of the SIMS (including FOMM) concept for TS. Hard data indicate that experienced and highly trained personnel can find more equipment faults with MDC supported by keyed schematics and keyed information. Such maintenance guidance, including the more elaborate FOMM, is inappropriate for the objective of maximizing the utilization of first-enlistment personnel.

8. A much higher percent of hardware faults will be isolated with the use of FPJPA for TS or LTTA (with controlled enrichment) than with the use of traditional data. But a backup capability of highly trained and skilled beyond-first-enlistment personnel will be required. For electronic hardware, quality schematics and theory of operation will be required for these people. The MDC would also improve their performance if the added expense can be shown to be cost effective. SIMS and FOMMs both can provide quality schematics and useful theory of operation and should be considered for these purposes.

9. A probably more effective and less costly scheme for providing such backup capability is a centralized maintenance information center, which can be called by phone whenever a difficult problem is encountered. A highly trained expert for each hardware system being maintained is assigned to such a center. A modification of this concept is being used successfully by the Office Products Division of IBM.

Training Establishments

1. As far as its effectiveness for DOD maintenance, the training of first enlistment personnel is a very costly and transitory undertaking. As such, its length should be minimized and decentralized as much as possible. The IBM use of TOT programmed instruction packages, coupled with improved maintenance guidance for local training of entry personnel, is a model that should be given serious consideration for DOD-wide application. If such a system was utilized by DOD, both the TOT training packages and the improved maintenance guidance would have to be tailored for *novice personnel*. But TOT and FPJPA technologies are available for fulfilling such requirements for DOD. As indicated previously, the Army has taken action to decentralize its entry training programs. However, few Army training packages and maintenance guidance documents are fully developed and operational, and their effectiveness for novice personnel has not been ascertained.

2. To insure maximum cost effectiveness from the implementation of a FPJPA/TOT model similar to that shown in Figure 2, the training and job success of first term DOD maintainers must be based on demonstrated ability to perform job tasks. This requires the utilization of JTPT batteries as the criteria for training and job success of first term maintainers, as well as the abandonment of traditional paper-and-pencil theory and job knowledge tests for such personnel. The TOT does not prepare people to pass such paper-and-pencil tests. With regard to an effective JTPT battery, FPJPA will provide for much of the interface between maintainer and his hardware. Therefore, if the maintainer can demonstrate his ability to perform a limited number of key and difficult tasks of his job (using FPJPA), plus his ability to use test equipment and hand tools, it can be assumed for sampling purposes that he can perform most of his job tasks. Because of this characteristic of the FPJPA/TOT trade-off, the amount and cost of training hardware necessary to provide hands-on practice of representative tasks for quality TOT (based on a quality FPJPA/TOT trade-off) should be much less than that required for quality TOT supporting the TMM.

3. It is proposed that the responsibility for conducting field TOT programs be given the maintenance establishment. This would fix the responsibility for training with the people who must live with the results. In addition to conducting the broadbased training for second term personnel, the training establishments should have the job of preparing and updating the TOT packages, as well as of training the appropriate members of the maintenance establishment to conduct such TOT.

4. Although shorter than conventional training, quality TOT is not cheap training. Most of the training time (to be effective) must be spent in "hands on" practice of key job tasks. This type of training cannot be obtained in "training" facilities consisting of classrooms, podia, tablet armchairs, blackboards, and projectors. Effective TOT requires substantially higher instructor-to-student ratios than DOD manpower establishments are accustomed to tolerate. Such training also requires larger investments in hardware, hardware simulators, pictorial simulators, and part-task trainers. So the per week or per day cost of TOT will be greater than conventional maintenance training, especially for electronic hardware. For example, the highly concentraled TOT program, which is only a fourth as long as a conventional program may cost four or five times as much on a weekly basis, thus making the total operating cost of producing a graduate the same or slightly more than the total cost of the current program. Budget managers must realize that this is another price that must be paid to reduce the LCC.

5. To insure the integrity and effectiveness of both the initial TOT and the associated JTPT batteries, job assessment centers are proposed. Each proposed center would operate as a joint effort with the appropriate training establishment. Selected graduates of entry training programs should be given a battery of JTPT, which would ascertain the effectiveness of entry training programs. The same job assessment center could be used to ascertain the job effectiveness of randomly selected experienced maintenance personnel. The bank of data obtained from such centers should be used to standardize entry aptitude tests.

6. As to the effectiveness and future of centralized and general training for first term maintenance personnel, it would be impossible for DOD training establishments to provide "hands on" TOT training for the maintenance of all hardware systems and subsystems for many of the current personnel assignment codes. In this regard, the present long, theory bases courses now given to entry maintenance personnel for the broadbased assignment (specialty) codes are not designed to permit early utilization of first enlistment personnel. The only hope for effective and efficient first enlistment *general* and/or centralized training for maintenance is the successful application of the following hypothesis. A formal *centralized* "hands on" TOT program can be developed, the content of which would be built around typical hardware from a cluster of similar hardware and would be ascertained by a very careful TOT/FPJPA trade-off for that hardware. During this course, the novice would learn to use the required test equipment and to perform all key maintenance tasks on the selected hardware. His success would be determined by his ability to pass the JTPT. FPJPA based on similar FPJPA/TOT trade-offs would be developed for the *other* hardware of the cluster. A strong hypothesis, supported by some research results, is that the novice would be able to perform maintenance on the similar hardware using FPJPA with a minimum of field orientation TOT on the unfamiliar hardware. The "hands on" exercises for centralized TOT can be provided on a proper mix of actual hardware, part-task trainers, photographic trainers, and computer controlled trainers. The testing of this hypothesis is one of the R&D efforts which the Air Force training establishment has not yet undertaken.

The Maintenance Establishment

1. If improved guidance materials for the performance of maintenance tasks are to be effective, the DOD maintenance establishments must properly utilize them. This will require changes in the work habits of some maintenance personnel. Such changes will not be made easily.

2. The maintenance establishments must also make maximum use of first enlistment personnel. Such personnel will be assigned to many maintenance tasks that have been performed in the past by people with more time in service. This will require changes in the habits and attitudes of maintenance supervisors and superintendents.

3. If the responsibility for conducting initial training is assigned to the maintenance establishments, they must be manned for it. Those responsible for such training should themselves be well trained for the job. Such training cannot be made an additional duty of already overworked supervisors who are inadequately prepared for such tasks.

4. Such changes will require well planned and executed initial implementations and long term follow-ups. Among other things, supervisors and already-in-place workers must learn and use the new maintenance directions. Not liking to do something can not be accepted as a valid excuse for not doing it. Many times after the initial resistance to change is overcome, affected people wonder why they were against the change. For example, many pilots initially resisted the requirement for them to conduct preflight inspections, but now it is an unquestioned part of a pilot's job.

Integration and Implementation Mechanisms

1. The existence of specification and other guidance documents (which accurately reflect IMG&I and TOT technologies) does not insure that individuals within the affected establishments will or can properly implement such technologies. Technologies (such as, FPJPA, FORECAST, TOT, and JTPT) require many people in the training, personnel, maintenance, maintenance manual, and industrial establishments to modify or change many of their long-standing attitudes and behaviors. In addition to overcoming their natural resistance to change, many of these people must learn important tasks and skills which they do not now possess. These problems call for well planned and executed actions including the following:

a. Appropriate training programs concerning improved technologies for affected managers, supervisors, and journeymen. The programs should result in certification for both DOD and contractor personnel, based on supervised practice and demonstrated ability to perform the required skills. These training programs should stress the required integration of technologies. (The certification of contractor personnel may require some modification of current DOD policies.)

b. The establishment of DOD in-house capabilities to perform in-process review of contractor developed subproducts of TI&A and the application of these subproducts to IMG&I and TOT developments.

c. The establishment of an appropriate mechanism for insuring the effective integration of IMG&I, TOT, and JTPT technologies.

2. The tremendous savings to be realized from the implementation of IMG&I, TOT, and JTPT will be reflected in the maintenance establishments. However, the substantial investments required to effect these savings must be made by the technical manual, training, and personnel establishments. Currently, the effectiveness of managers in each of these affected establishments is not measured by the savings they effect in the maintenance establishments. Current funding practice uses past expenditures for each individual establishment as budgeting criteria for its future expenditures. A mechanism must be established which will provide sufficient additional funds for these necessary investments in quality IMG&I, TOT, and JTPT.

3. An important consideration for the development of DOD policy encouraging effective applications of IMG&I, TOT, and JTPT technologies is their potential for rapid buildup of both new and reserve personnel in times of national emergencies. In-place, quality integrations of FPJPA, TOT, and JTPT technologies for key hardware would not only greatly reduce buildup time but would also reduce the number of spare parts used at a time when they would probably be in short supply.

4. Since so many now independently operating establishments must work in concert, an agency must be established having the necessary power and "know how" to effect the necessary changes. The Office Products Division of IBM accomplished this important function by making the same general manager responsible for the development and conduct of formal training, the development of field training packages, the development of on-the-job task guidance documents, the development and validation of aptitude tests,

and the conduct of the job assessment center. This structure provided the necessary power to effect such an integration, but the necessary "know how" was provided by an expert human engineer, and management followed his directions. The application of power unaccompanied by in-depth "know how" is a dangerous combination when dealing with complex technologies.

5. The Army has provided the controlling function for their Integrated Technical Documentation and Training (ITDT) efforts by establishing the ITDT General Officer Steering Committee. This committee is made up of 10 generals and one civilian director holding key positions from the (US Army) Training and Doctrine Command (TRADOC), Material Development and Readiness Command (DARCOM) and Forces Command (FORSCOM). Such a group certainly has the power to effect such an integration. For success, ITDT must use the most effective maintenance guidance documents that the state-of-the-art can produce; however, the specification and handbooks provided for this integration will not ensure the development of effective maintenance guidance. The probable consequence will be lower than expected results and, in some cases, failures, which should not be blamed on weaknesses of either the FPJPA or TOT technologies. The ITDT concept is the first large scale attempt by a service of DOD to effect better utilization of first enlistment personnel by the combined use of TOT and improved maintenance instructions. Such a sincere and worthy effort can fail, however if the effectiveness of the maintenance instructions and training is less than the state-of-the-art can provide.

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APPENDIX A: TRADITIONAL MAINTENANCE MANUALS (TMM): A DESCRIPTION AND MANPOWER CHARACTERISTICS

Traditional maintenance manuals (called technical orders (TO) by the Air Force) have come to contain three types of data that directly impact maintenance; namely, (a) step-by-step directions for some non-troubleshooting (non-TSO) tasks, (b) limited guidance for troubleshooting (TS) tasks (such as symptom-cause charts or traditional logic trees), and (c) hardware information including schematics and pictorials to support TS.

Traditional Step-by-Step Procedures for Non-TS Tasks. For many years maintenance manuals have included step-by-step procedures for some non-TS tasks such as checkout procedures; align, adjust, and calibrate procedures; remove, replace, and repair procedures; and servicing procedures. No methods or standards were available to evaluate such procedures as to the completeness of coverage of all job tasks, as to the development and evaluation of such directions in terms of a standard language, as to the development and evaluation of standard pictorial location information to support the standard directions, and as to a determination of a consistent level of detail for the information for all such directions. As a result, such directions are not written in standard language, directions vary in length and complexity, and very few pictorials are used to support the written directions. From time to time, ad hoc efforts have been made by various individuals and groups to improve such instructions, but these improvements were seldom if ever institutionalized. Consequently, improvements have not had wide application.

Traditional Directions for TS. Traditional maintenance manuals provide symptom-cause charts and/or unenriched logic trees for troubleshooting guidance. At best, either of these items provide rather limited coverage to the problems facing a troubleshooter. Symptom-cause charts do not contain all the trouble symptoms that a system can develop, and many times the number of causes displayed for a given symptom is not complete. Logic trees in their traditional form do not display appropriate information for each decision point. When using either of these directive items, the technician must know the geography of hardware and be extremely familiar with the nomenclature of the parts of the specific hardware on which he is working. After making use of the limited guidance provided by either of these devices, the technician must plot his own course of action and glean the necessary support information from the information categories of the maintenance manual. To successfully use these materials and get most TS tasks accomplished in a reasonable time, the technician must be highly trained. He must be extremely familiar with the TO information, with the geography of the equipment, and with the function of each unit of the equipment under test.

Traditional Information Categories for TS. In addition to the directions found in symptom-cause charts and logic trees, a number of categories of information which support TS are usually presented in traditional maintenance manuals. These categories include block diagrams, schematics, flow diagrams, normal reading and/or tolerance charts, theory of operation, pictorial location diagrams, aircraft wiring diagrams, and illustrated parts breakdowns. Most of these items were developed to support the original manufacture of the hardware and, although they contain much information of use to the troubleshooter, they were not human engineered for his use as to content, format, or organization.

The isolation or identification of faulty components in complex mechanical and/or electronic systems has always been an expensive process in terms of technician time and the number of spare parts used. There is some evidence which indicates that many technicians have only a limited facility for troubleshooting systematically. When this limited systematic approach is not successful, they fall back on the removal and replacement of components until the system becomes operational (Folley & Elliott, 1967). Although this shotgun approach usually works, it is very expensive in terms of the number of spare parts used, and the secondary damage caused by unproductive and unnecessary remove and replace actions.

Manpower Characteristics Required for Traditional Manuals (Non-TS Tasks and TS Tasks)

1. The maintainer must know the geography of the hardware on which he is working.

2. The human must make up for the weaknesses or lack of the step-by-step instructions for tasks. Where instructions do not exist or instructions are not suffciently comprehensive, he must plot his own course of action. Where steps or cues are missing in task instructions, he must compensate for such deficiencies.

3. Many maintenance managers *contend* that extensive fundamentals (theory) training, as well as knowledge of theory of operation for the hardware, are necessary prerequisites for performing maintenance tasks with such instructions. These contentions are especially strong in electronic maintenance establishments.

4. Only high aptitude people can successfully complete such training programs.

5. There is no doubt that extensive experience in maintaining the hardware is required for *effective* maintenance with such uncontrolled maintenance guidance and information.

6. For effective maintenance, the maintainer must also be proficient in his use of test equipment.

Added Manpower Characteristics Required for Traditional Manuals (TS Tasks)

All of the characteristics required for non-TS tasks also, apply to TS tasks. In addition, TS tasks are generally more demanding of maintenance technicians than non-TS tasks. There are many factors that contribute to this demand, some of which follow.

1. The troubleshooting process most times should include the accomplishment of various mixes of non-TS tasks, as well as proficient use of several test equipments.

2. Since most traditional maintenance manuals contain very limited directions for TS tasks, the maintenance technicians must plot their own course through this maze of activities. For effective TS, using such manuals, the technicians must possess and use an effective TS strategy.

3. The following of such a strategy usually requires a high degree of persistence. The strategy must be interrupted many times to gather test point information. If the test equipment is not used accurately, the result is false test point information which reduces the effectiveness of the strategy. There is always the temptation to gather more than the necessary information in the area of a test point and, thus, lose track of the strategy.

APPENDIX B: DESCRIPTION OF SEVERAL TYPES OF IMPROVED MAINTENANCE GUIDANCE AND INFORMATION (IMG&I)

During the past 20 years, several programs have been directed toward improving the effectiveness of maintenance manuals as sources of job directions for maintenance at the Organizational (O) and Intermediate (I) levels. Shriver and Trexler (1966) provide a summary of most of the earlier efforts. However, there are five main sources of new categories of directions and information; namely, the Symbolic Integrated Maintenance System (SIMS) concept, the Air Force Presentation of Information for Maintenance and Operation (PIMO) Project, the work of the Air Force Human Resources Laboratory (AFHRL), the Air Force Vietnamization Projects, and the Army's FORECAST Project accomplished by the Human Resources Research Office (HumRRO). The SIMS concept produced a new troubleshooting (TS) tool, i.e., the maintenance dependency chart (MDC), as well as reformatted schematic and theory of operation information. The PIMO project produced the fully proceduralized job performance aid (FPJPA) for only the non-TS tasks, and the AFHRL work produced FPJPA for both non-TS and TS tasks. The PIMO project, among other things, simplified the MDC. The Vietnamization efforts systematized the production of FPJPA for non-TS tasks and TS tasks, as well as for MDC. The FORECAST project was primarily a training project, but it produced another type of TS aid, and enriched blocked information flow diagram called the Cue Response Set.

In one sense, the SIMS effort started with the existing technical order materials and attempted to improve format and content of TS directions and information for use by the maintenance technician. The AFHRL work started with a study of the TS and non-TS tasks of the maintenance job and developed new types of directions that would guide the performance of each type of task. The PIMO project contains elements of both these approaches. All can make certain contributions toward improving the efficiency of maintenance or training or both. An overriding consideration for the application of any of these concepts or technologies is what each can do for the first term maintenance technician in terms of increased time during this enlistment as an efficient and productive worker. A closely related factor is the potential of each for the reduction of "buildup" time for national emergencies.

Symbolic Integrated Maintenance System (SIMS) Including the Functionally Oriented Maintenance Manual (FOMMs)

The original system provided for both non-TS and TS tasks; the directions for non-TS tasks generally had the same limitations as traditional maintenance manuals. The main thrust of SIMS and FOMMs has concerned improved directions and information for TS. For TS, the SIMS concept has substituted a much more powerful aid than either the symptom-cause chart or the traditional logic tree: the MDC. This MDC is in the form of a matrix. It is a structured presentation of both directions and information. On the Y axis of this matrix is placed a systematic step-by-step checkout procedure. (Although such instructions could be presented in standard direction language, currently such directions vary in length and comprehensibility.) When followed, this procedure will produce out-of-tolerance conditions or symptoms when the system is not functioning normally. On the X-axis of this matrix are placed all of the functional units of the system. A rather complex set of symbols is provided for the cells of the matrix which indicates the desired equipment responses for each step of the checkout procedure and identifies the set of functional units that can cause such an out of tolerance condition. But, once this set of functional units (dependencies) is identified, the technician must plot his own course for determining which functional unit in the set is faulty and to troubleshoot and to repair the faulty functional unit. Great care must be taken in developing MDC to insure that each set of functional units is complete. As to sets of symbols, several have been developed by various Navy and Air Force efforts. The degree of complexity has varied greatly from set to set.

The SIMS concept provided improvements in organization of information to support TS. The blocked schematic of the SIMS concept combined much of the information presented in traditional maintenance manual block diagrams, schematics, flow diagrams, and normal reading and/or tolerance charts. The schematics are reorganized and placed in blocks of shades of gray or blue. Each block (or sub-block) represents a black box or a functional unit of a black box. The theory of operation of the traditional maintenance manuals was reorganized into similar blocks so that the technician can more easily find a statement as to the operational function represented by each major block of the blocked schematic. In SIMS, the pictorial location diagrams are replaced by pictorials with location grids such as are found on road maps. Due to the color requirement, the printing of block schematics and blocked information is expensive. In addition, many times a block is not large enough for complete functional information.

Navy Implementations of SIMS and FOMMs. Most of the DOD efforts for the production of SIMS aids have been accomplished by the Navy. Over the years the Navy has issued three specifications based on the SIMS concept Mil-M-24100 (SHIPS), 1 Dec 1964; Mil-M-24100A (SHIPS), 15 Jun 1966; and Mil-M-24100B, 2 Jan 1974. The first two, both entitled "Manuals, Orders, and Other Technical Instructions, for Equipment and Systems," follow the original SIMS concept very closely. The most recent specification (2 Jan 1974), entitled "Manuals, Technical: Functionally Oriented Maintenance Manuals (FOMM) for Equipment and Systems" calls for a more complex and detailed set of symbols for the MDC. As with the original SIMS, these specifications provide for a complete data package for both TS and non-TS activities. However, the directions for non-TS activities are similar to those provided by traditional maintenance manuals.

Air Force SIMS Work

The Air Force operational implementation of SIMS type aids has been rather meager when compared to the Navy. Most of the work has been limited to tryouts and evaluations, development of specifications and very limited implementations. All Air Force SIMS efforts have been limited to the support of TS tasks.

Air Force Logistics Command (AFLC) supported a rather broadbased development and tryout of SIMS type aids in the middle 60s. The aids developed for this project included traditional SIMS information, blocked schematics, and blocked information. Although a formal report of the outcome was never published, the results of tryouts of these data were generally positive. One output of this tryout was the development of MDC, blocked schematics, and blocked information for the voice omnirange equipment. These data were used by the Air Force Communications Service (AFCS) for several years. When the data wore out from use, AFLC was unable to replace them. Another output of this effort was draft specification Mil-M-38799 (USAF), 15 Oct 69.

The only hard data available which compare the effectiveness of SIMS, TS aids and traditional maintenance manuals was generated by the PIMO project. This project evaluated a modification of SIMS type aids for organizational troubleshooting tasks. The aids developed for the C-141 aircraft included MDC, as well as key schematics and keyed information. The results indicated that *experienced* maintenance technicians could find 90 percent more troubles on their first troubleshooting attempts than when using traditional maintenance manuals (AFSC-TR-69-155(I), 1969).

The requirement for hard data comparing the relative effectiveness of FPJPA and SIMS was reflected in the original AFHRL advanced development plan prepared in 1967. It called for comparing FPJPA, SIMS and traditional maintenance manuals. In anticipation of this comparison, SIMS data were prepared for the Doppler radar, AN/APN-147, and for its computer, AN/ASN-35. Due to lack of funding, the comparison was never conducted. As a result, the requirement for such comparative hard data still exists.

The only official Air Force SIMS type specification, Mil-M-38799 (USAF), was published 15 Aug 71. This document called for an improved MDC. Each functional unit listed on the X axis is keyed to a pictorial which indicates to the technician how the functional unit looks and where it is located. All of the hardware items mentioned in the checkout procedures are also keyed to pictorials. Such MDC were first developed for the UH-1H as part of the Vietnamization program. These MDC were first specified in Mil-J-83302, the

Vietnamization specification. (It should be noted that the latest FOMM specification, Mil-M-24100B (2 Jan 1974), does not call for these pictorial locators.) The PIMO MDC and the MDC specified in Mil-J-83302 and in Mil-M-38799 (USAF) (15 Aug 71) called for a less complex set of symbols than that required by the original SIMS concept and by Mil-M-24100B.

After the UH-1H effort, the job performance aids produced for other Vietnamization projects did not include SIMS type data. Concerning SIMS type data for Air Force hardware, such data have been official Air Force technical order (TO) materials since 1968. Their status has been that they were available to requesting Air Force agencies provided that their requirement was justified and that sufficient funding was available. Their development has not been mandatory. No Mil-M-38799 SIMS type data have been generated for the Air Force since their official acceptance.

Evaluative Statement

SIMS directions (including FOMMs) for non-TS tasks are no more effective than similar directions found in traditional maintenance manuals. Well designed SIMS aids for TS tasks will improve the troubleshooting performance of many highly trained and experienced maintenance technicians. All users have been high aptitude personnel. The key to this improvement is the MDC which requires the user to learn a unique and rather complex symbology. The MDC provides a fixed strategy which gets the user into the right "ball park." However, SIMS aids will do little to increase the effectiveness of each first term maintenance technician in terms of increased time as an efficient and productive worker or to reduce the high aptitude requirement of such personnel. SIMS type data, and especially FOMM, are very expensive to develop and produce. In addition, to date no one has given adequate consideration to the problems and costs of updating such data.

Fully Proceduralized Job Performance Aids (FPJPA) Technology

FPJPA is the generic name of a technology which can be used in the development of step-by-step directions for both non-TS and TS tasks. The current technology contains aspects obtained from several sources (see Table 1 in this report) including the AFHRL exploratory development efforts, the first AFHRL advanced development effort (1967--1972), the PIMO project, JPA projects for Vietnamization and the development of aids for the C-141 aircraft. Apprendix E provides a summary of Air Force, Army and Navy R&D FPJPA efforts concerning only non-TS tasks. In addition, the Air Force and Navy have had FPJPA R&D efforts concerning TS tasks, and both TS and non-TS tasks. The Navy has completed one effort concerning the FPJPA/Task Oriented Training (TOT) trade-off and is now contracting for further R&D concerning this area. Each of the efforts will be discussed at an appropriate place in this paper.

The FPJPA concept did not emerge as a true technology until specification and guidance documents were developed for the Vietnamization projects (Mil-J-83302). Currently, AFHRL-TR-73-43, a three volume report, provides the best description and directions concerning the FPJPA technology for both non-TS and TS tasks (see Joyce et al., 1973a, 1973b, 1973c). The most important addition to this report is found in AFHRL-TR-75-38 (Shriver, 1975) concerning improved cues for step-by-step directions. This AFHRL-TR-73-43 reflects the lessons learned in applying the Vietnamization documents. To assist the reader in assessing recent maintenance manual developments, several key characteristics and requirements of the FPJPA technology are outlined and briefly discussed.

Task Identification and Analyses (TI&A) of Identified Tasks

A unique characteristic of this technology is the formal requirement for the development and use of TI&A. To ensure the effective job support for non-TS by FPJPA, an aid must be considered for every task of a hardware to be maintained. Each FPJPA must contain accurate and complete step-by-step instructions, keyed to pictorial locators for its task. And each FPJPA must contain all of the cues necessary for individuals of the target populations to perform the task.

FPJPA for TS tasks must be built around a logic or troubleshooting tree that identifies all the troubleshooting signatures. There must be a signature for each replaceable component assigned to the level of maintenance for which the TS aid is being developed. For each decision point in the TS tree, accurate step-by-step instructions, with the necessary cues, must be developed.

To ensure the completeness and adequacy of the required product of formal TI&A, there must be timely periodic in-process reviews and official acceptance of these products by knowledgeable DOD representatives. These products then become the criteria for the structure and completeness of the FPJPA to be used during their development.

Standard Language and Keyed Pictorials for Maintenance Instructions

Another unique characteristic of FPJPA coming from the PIMO project is a standard language. Each maintenance direction is limited to a total of three sentences and a total of 25 words. Each of these sentences is limited to 10 words. The first word of each sentence is an action verb in the second person taken from a standard verb list. In addition to standard verbs, all nouns are cross-referenced (keyed) to a locator pictorial which indicates to the user the appearance of the item and its location in the hardware.

This standard language provision coupled with the pictorial locators reduce the reading-level requirements of the user to a minimum. The user must recognize and know the meaning of a limited number of action verbs. Since these verbs are basic to his specialty, the user must learn the meaning of these verbs if he does not already know them. The meaning of each noun is provided by the keyed pictorial locators – no matter how many letters there are in each noun. No sentence is over 10 words. Under these conditions, the results of reading index applications, which are based only on word and sentence lengths, become meaningless when applied to these instructions.

Format

A properly developed and utilized TI&A, as well as standard language and keyed instructions, are necessary ingredients of the FPJPA technology. Using these as foundations and considering the job environment in which the identified tasks were to be accomplished, several appropriate formats have been developed to date. But an important item to remember is that the necessary content of the aids is far more important than the format.

A format similar to that developed for the PIMO project has usually been used for non-TS tasks at the O level of maintenance. Instructions have been formatted in a rather small booklet with instructions on the left-hand page and the locator pictorials on the right-hand page. Some applications have provided pictorial foldouts, each applied to more than one page of instructions.

There has been only one development of FPJPA for the I level of maintenance for non-TS tasks: the AFHRL aids for the AN/APN-147 and the AN/ASN-35. These aids were similar to O level aids except that they were formatted in standard TO-size books (8 by 10½ inch pages).

There have been two formats used for FPJPA for TS tasks, one in which the instructions have been placed in blocks and the blocks connected by flow lines to indicate branching, similar to Logic Tree Troubleshooting Aids (LTTA), and, the other, in which the instructions have been placed in a scrambled book. The scrambled book format produces a document that looks very similar to FPJPA for non-TS tasks. The branching in the scrambled book is provided by directions to go to the page on which the instructions are given. (This format provides for much simpler updating than the blocked LTTA format.) The draft specification found in AFHRL-TR-73-43(I) (Joyce et al., 1973a) provides for only the scrambled book format. The earlier draft specification found in AFHRL-TR-71-53(I) (see Folley, Joyce, Mallory, & Thomas, 1971a) provided for a choice of the scrambled book or the logic-tree-like format.

Future applications of the FPJPA technology may result in other formats that will better meet the needs of some users. The point is that the FPJPA technology is not limited by format, nor is it truly represented by format. For it is possible to apply any of the formats mentioned here, without the *content* control of the TI&A, but such applications cannot legitimately be considered true implementations of the FPJPA technology.

Validation, Verification and Warranty of Maintenance Manuals

Validation by the contractor, followed by verification by the Air Force, has long been part of TO policy. In some cases these requirements were only table top inspections of the final products. However, in the past, with the exception of corrections for obvious errors in directions and format, little could be accomplished by these processes to insure the job effectiveness of maintenance manuals. Several applications of the FPJPA technology have indicated that, no matter how carefully the TI&A was accomplished and monitored and no matter how carefully the resulting criteria were applied, a very careful "hands on" validation and verification of the results are required. For maximum effectiveness, one of these efforts should include "hands on" equipment tryout of directions by members of the target populations for which the directions have been developed.

Another safeguard which was applied in developing aids for the C-141 aircraft was a 3-year warranty by the contractor of his product. To insure maximum effectiveness of the FPJPA technology, such warranties should be obtained for all future applications.

Applications of the FPJPA Technology

Since some recent applications of the FPJPA technology have been mixed with the application of enriched LTTA and FORECAST concepts, a discussion of these concepts will precede the discussions of Air Force, Army and Navy applications of the FPJPA technology and other maintenance manual improvement efforts. In such discussions in this appendix, a maintenance manual development, to be considered an implementation of the FPJPA technology, must include the proper development and utilization of TI&A and must include the use of the standard language outlined in this section.

Enriched Logic Tree Troubleshooting Aids (LTTA)

As indicated in Table 1 of this report, enriched LTTA was one type of TS data evaluated as part of the 1973 advanced development project 1194 concerning FPJPA. LTTAs for the O level of maintenance for the Doppler radar, AN/APN-147, and its computer, AN/ASN-35, had already been developed as part of the C-141 data improvement effort. These already available O level LTTAs were used for project 1194. Only the LTTA for the intermediate level of maintenance was procured by AFHRL.

Both the O and I level LTTAs differed from traditional LTTA in three important respects. *One*, the contract work statements called for "front end" analyses, very similar to the TI&A required by the FPJPA technology used for developing the FPTA for the same project. These analyses assured that all trouble signatures were identified. *Two*, there were in-process reviews by an Air Force maintenance team of these analyses, as well as of the resulting logic trees. *Three*, the logic trees were greatly enriched by the inclusion of a large amount of directions and information at each decision point in the logic trees.

An important difference between the FPTA, developed with FPJPA technology, and these LTTA developments was the difference in specification and control of the amount of enrichment to be added to the basic logic trees. For the FPTA development the amount and kind of enrichment was controlled by using the draft specification in AFHRL-TR-73-43(I) (Joyce et al., 1973a). Since no LTTA specification was applied to either the O or I level LTTA, the amount of enrichment was left to the discretion of each developer. The developer of the O level LTTA who had previously developed FPTA, included pictorial locators as part of the LTTA directions and information. However, the I level LTTA did not contain such pictorials. And, in general, the O level LTTA directions and information were more detailed (enriched). In fact, they approached the level of detail of the FPTA. Since the Air Force guidance provided to both developers was very similar, these two LTTA developments provide an example of the variance in LTTA content which can be expected from different LTTA developers when the amount and kind of enrichment is not specified.

In this regard, AFLC recently prepared a request for personnel research (RPR 77-19) entitled "Development of Specifications for Maintenance Task Analysis and Logic Tree Troubleshooting Aids." This RPR asks that AFHRL develop two specifications: one, for "front end" analyses which will be applicable for both non-TS Job Guide Manuals and LTTA and the other, a format specification for LTTA. When developed, the combination of these specifications should result in more consistent enrichment of LTTA.

APPENDIX C: ARMY FORECAST PROJECT

FORECAST was a Human Resources Research Organization (HumRRO) project supported by the Army and directed by Dr. Edgar L. Shriver (see Shriver et al., 1964). The primary objective of the study was to shorten training time by restructuring the Army M-33 fire control technician job. This was accomplished by simplifying the performance of maintenance job (especially TS tasks) with improved maintenance guidance and the application of TOT program tailored to the modified job. As such, it was the first IMG&I/TOT trade-off study.

The development of the original FORECAST aids required a functional analysis of the hardware for which aids were developed. This analysis resulted in a block diagram showing signal or information flow. The aids called "cue response sets" provided and emphasized normal input and output information for each block. The more recent modification of such aids recommended by Shriver and Hart (1975) and specified in Army draft Mil-M-632XX, Part I has added pictorial locators for input hardware test points.

Evaluative Statement

Although the effectiveness of such aids is supported by a carefully conducted and well reported controlled study (Shriver et al., 1964), there are no hard data comparing the effectiveness of FORECAST TS aids with FPJPA or LTTA. The author estimates that the FPJPA for TS is somewhat more effective for newly assigned first term enlistees. This estimate is based on the assumption that the FPJPA for TS relegates more to the "book" and less to the "head" than do the FORECAST aids. But there are no comparative hard data to support this estimate. At the time the Shirver and Hart (1975) recommendations for TS aids were made for the Army, the results of the AFHRL FPJPA study (Potter & Thomas, 1976) were not available.

APPENDIX D: AIR FORCE R&D EFFORTS CONTRIBUTING TO FPJPA TECHNOLOGY

1961 – 1977 AFHRL Exploratory Development Efforts

Key Products

1. Maintenance Task Simulator (Elliott & Folley, 1964; Elliott, 1967b, 1967c)
2. Field Survey of Maintenance Practices (Folley & Elliott, 1967)
3. Americanization of Vietnamization Specification and Handbooks (Folley et al., 1971a, 1971b; Joyce et al., 1971)
4. Refinement of Americanized Draft Specification and Handbooks (Joyce et al., 1973a, 1973b, 1973c)
5. A Proposal for a Modified Technical Order System (Foley, 1975)
6. Comparative R&D (see results below)
7. Survey of Acceptance and Usability of Job Guides for C-141 Maintenance

Results of Comparative R&D

1. High school subjects with 12 hours of training using FPJPA: high aptitude subjects (80 thru 95 percentile) found 93 percent of troubles and medium aptitude subjects (50 thru 65 percentile) found 83 percent of troubles (Elliott, 1967a).
2. Air Force experienced subjects using TMM found 84.2 percent of troubles (Elliott & Joyce, 1968).

Results of Job Guide Survey (Johnson, Thompson, & Martin, 1977)

1. Results of interviews, questionnaires and observations indicate that C-141 job guide program is successful.

1964 – 1969 AFSC presentation of Information for Maintenance and Operation (PIMO) Project

Key Products

1. PIMO type FPJPA for O level, non-TS Tasks for C-141 Aircraft (AFSC-TR-69-155 Vols I – VIII)
2. Modified SIMS for O level TS tasks for C-141
3. Comparative Study: FPJPA (non-TS tasks) vs TO; SIMS (TS tasks) vs TO.

Results of Comparative R&D (AFSC-TR-69-155(I))
(All high aptitude subjects)

1. Apprentices and experienced Air Force specialists performed non-TS tasks with no measurable errors when using FPJPA. Both made errors using TO. Apprentices could not complete many non-TS tasks using TO.
2. Experienced Air Force specialists reduced TS errors by 92 percent when using modified SIMS aids.

1969 – 1972 USAF Vietnamization Project

Key Products

1. PIMO type FPJPA for three hardware systems for O level TS and non-TS tasks; also PIMO type SIMS TS Aid for one system.

2. Converted FPJPA concept to technology – Mil-J-83302, handbooks for JPA developers and managers.

3. Applied this technology to seven hardware systems (O level TS and non-TS tasks) (Appendix F).

4. Articulated cuing requirement for FPJPA directions AFHRL-TR-75-38 (Shriver, 1975).

5. Evaluation of UH-1H Aids (Shriver & Foley, 1975).

1967 – 1972 First AFHRL Advanced Development Effort

Key Products

1. Pre-specification FPJPA for TS (AN/APN-147 and AN/ASN-35)

2. SIMS type TS aids (AN/APN-147 and AN/ASN-35)

3. Programmed Instruction on use of SIMS aids

4. Demonstration of FPJPA/TOT trade-off (Mullen & Joyce, 1974)

5. Plan for comparative controlled R&D

Plan for Comparative, Controlled R&D

1. Multi-variant design considering FPJPA vs. SIMS vs. TO; high vs. medium aptitude; traditional training and TOT trade-off with FPJPA; and transferability from TOT/FPJPA on one hardware to FPJPA on other hardware. (Funds withdrawn – project cancelled 1972.)

1973 – 1976 Second AFHRL Advanced Development Effort

Key Products

1. FPJPA for both O and I level TS and non-TS Tasks (FPJPA for TS tasks called FPTA)

2. LTTA for O level TS tasks with pictorial locators (Borrowed from C-141 TO improvement program)

3. Phase I R&D – comparative study

4. Phase II R&D – Plan for FPJPA/TOT trade-off study

Results for Phase I Comparative R&D (High Aptitude Subject only)

1. FPTA vs. LTTA vs. TO – See Tables 1, 2, 3, and 4. (Potter & Thomas, 1976; Potter et al., 1976a, 1976b.)

Plan for Phase II Comparative R&D (High Aptitude Subjects only)

1. Design considered only TOT tailored for FPJPA plus FPJPA vs. TOT tailored for TO plus TO. Design did not consider medium aptitude subjects or transferability from TOT/FPJPA trade-off on one hardware to FPJPA on other hardware. (Funds withdrawn; project cancelled.)

APPENDIX E: SUMMARY OF CONTROLLED COMPARATIVE TRYOUTS CONCERNING FPJPA TECHNOLOGY FOR NON-TS TASKS

The most extensive controlled tryout of FPJPA for non-TS tasks, which contributed to the technology, was made as part of the PIMO project. In addition, the Navy and Army have conducted less extensive tryouts of similar data.

The PIMO Project

The PIMO project included two early exploratory development R&D efforts and an advanced development operational R&D effort. A complete description of the project and its results are found in the eight volumes of AFSC-TR-69-155. One of the exploratory efforts and the advanced development effort were conducted under contract for the Air Force by Serendipity, Inc., of Chatsworth, California. The principal investigator was Dr. Kay Inaba, now Preseident of XYZYX Information Corporation of Canoga Park, California. This project was managed by the Ballistics Systems Division (now the Space and Missile Systems Office) of Air Force Systems Command (AFSC). Although not an AFHRL project, the Advanced Systems Division of AFHRL was represented on the PIMO working group from its start in 1964. The project was completed in 1969. From a money point of view, this one project was a much larger effort than all of the AFHRL efforts. The PIMO project cost $2,700,000.

The PIMO advanced development R&D, as planned, was to include the development and operational evaluation of advanced type job performance aids for both O and I level maintenance tasks for the C-141A aircraft. Fully proceduralized aids were to be developed for all tasks except electronic troubleshooting tasks and engine tasks. SIMS type aids were to be used for troubleshooting. The FPJPA were to be presented in both a hardback or book mode and a rapid access audiovisual mode.

A large scale field evaluation was planned to compare the relative maintenance effectiveness for non-TS tasks of traditional Air Force maintenance manuals, hardback FPJPA and audiovisual FPJPA. Due to a cutback in funding, the aids for I level maintenance tasks were not developed.

This experiment was originally designed for obtaining systems effectiveness information using gross effectiveness measures, such as down time and turnaround time using only those maintenance tasks that presented themselves in the operational flight line environment. This design proved to be unworkable. One of the problems was that tasks could not be matched for the various treatments of subjects. As a result, a controlled study based on a counterbalanced design was used. Like non-TS tasks were performed by each subject in the control and experimental groups. The results of this study are summarized in the following paragraphs.

1. Essentially no difference in *performance time* for experienced specialists performing with FPJPA aids and for those performing with conventional T.O. aids and information. These experienced specialists averaged 25 years of age and approximately 19.2 months experience (5 and 7 skill levels).

2. These experienced specialists made *errors* when performing with traditional maintenance manuals. *No* errors were made when these specialists used FPJPA.

3. The apprentices performing with PIMO aids required *slightly less* time on the average to complete the maintenance tasks than the experienced specialists performing with PIMO aids. These apprentices averaged 20 years of age and approximately 5 months exposure to the C-141 aircraft, but they had no previous experience on the tasks used in the experiment.

4. *No* errors were made by the apprentices when using FPJPA aids.

5. These same apprentices required approximately a third more time to perform the tasks using traditional maintenance manuals and made more errors. These apprentices used the TO aids and information after they had performed the tasks several times using FPJPA aids. (Surprisingly, they made *fewer errors* than the experienced specialists using traditional maintenance manuals.)

6. A *second group* of apprentices was allowed to use only traditional maintenance manuals. This group required *much more time* and made *many more errors* than either the experienced specialists or the apprentices in the comparative experiment. In two of the three jobs, these apprentices were unable to complete the jobs.

7. A group of individuals from unrelated career fields was also given the same tasks to perform using FPJPA. Their performance was similar to that of the apprentices described in paragraph 3 and 4. They were able to perform the tasks very well with no errors.

8. No significant difference was found between audiovisual and visual (booklet) presentation of data.

Although the actual development of the PIMO FPJPA for non-TS tasks was preceded by a systems analysis and a so-called task analysis, these analyses were not as stringent as those now required by current technology (AFHRL-TR-73-43(I), Joyce et al., 1973a). In addition, these data were never given complete "hands on" validation and verification. So, the data would not meet the current requirements of the FPJPA technology. However, the PIMO FPJPA used for the tasks selected for the controlled experiment had been completely verified and probably would compare favorably with FPJPA developed in keeping with current technology.

An important contribution of the PIMO project to the FPJPA technology was the standard language for step-by-step directions supported by location pictorials. Its controlled experimental conditions provided sufficient and convincing hard data concerning the effectiveness of FPJPA for non-TS tasks. It demonstrated that experienced technicians would perform better maintenance if they used FPJPA. Important from the standpoint of better utilization of first enlistment personnel, it demonstrated that inexperienced personnel could perform non-TS tasks in a satisfactory manner using FPJPA. All of the personnel used for the PIMO study possessed high aptitudes.

Early Navy Development and Tryout of PIMO Type FPJPA

In the early 1970's the Naval Weapons Engineering Support Activity conducted a less extensive controlled evaluation of non-TS PIMO type FPJPA which were developed for an Auxiliary Power Unit – System No. NCA-8 under contract by XYZYX Information Corporation. The maintenance concept for this power unit required both electrical and engine specialists. During the study both types of the specialists were required to perform both electrical and engine tasks. An engine specialist was considered to be experienced subject on engine tasks and an inexperienced subject on electrical tasks and vice versa. The results, reported by Horne (1972), are very similar to those of the Air Force PIMO project.

1. Inexperienced subjects using FPJPA made no more errors than experienced subjects using traditional maintenance manuals.

2. The performance of experienced subjects was error free when using FPJPA. But they required more time than when using traditional maintenance manuals.

3. Before the FPJPA produced by contractor could be used effectively by the inexperienced subjects, they required complete "hands on" validation.

In addition, the Naval Air Systems Command had FPJPA developed for four different subsystems, each by one of four different contractors. These were developed under the Air Force Vietnamization specification Mil-J-83302 and its accompanying handbooks (Applied Science Associates, 1971a, 1971b). However, the Navy did not have the facilities for adequate in-process review and acceptance of the products of TI&A and to insure that these products were used as criteria during FPJPA development. Although each contractor delivered its FPJPA, they were never given a field evaluation.

Early Army Development of PIMO Type FPJPA

Also, in the early 1970's, the Letterkenny Army Depot at Chambersburg, Pennsylvania, developed FPJPA for six small items of equipment on an in-house basis. The systems included an armament pod for aircraft, a search light, a storage battery, a tank engine, a gasoline engine water pump, and a tow launcher. For a number of reasons, the evaluation of these aids was never completed.

APPENDIX F: SUMMARY OF USAF JOB PERFORMANCE AID PROJECT FOR VIETNAMIZATION

As part of the Vietnamization program, job performance aids (JPA) were developed to support maintenance of several hardware systems by maintenance personnel of the Vietnamese Air Force (VNAF). Fully proceduralized job performance aids (FPJPA) were developed for both TS and non-TS tasks. These aids were first developed for the UH-1H helicopter. In addition, SIMS type TS-aids were developed for this aircraft. Table F1 indicates the R&D sources of these different aids.

Table F1. **Indicating the Immediate Sources of JPA Data Selected for the Support of VNAF Organizational Maintenance of the UH-1H**

Types of Job Performances Aid (JPA) Data	Sources	
	PIMO Project 1964—1969	AFHRL Program 1961—Continuing
1. Fully Proceduralized Job Performance Aids (FPJPA) for Non-Troubleshooting Tasks (Job Guide Manuals)	X	X
2. FPJPA for Troubleshooting Tasks (called Fully Proceduralized Troubleshooting Aids-FPTSA)		X
3. Maintenance Dependency Chart (MPC) Centered Troubleshooting Aids	X	

Adequate specifications were not available for producing these UH-1H aids and the deadline for producing the UH-1H aids was very short. As a result, a sole-source contract was given to Dr. Kay Inaba's firm, the XYZYX Information Company. He had been the principal investigator on the PIMO Project and it appeared that he had the capability of meeting the short deadline.

While the UH-1H JPA were being developed, other JPA developmental efforts were directed for the VNAF. But before JPA could be procured on a multi-source basis, an adequate specification was necessary. A contract was let with Applied Science Associates, Inc., (ASA) of Valencia, Pennsylvania, for a specification (Mil-J-83302) and companion guidance handbooks (Applied Science Associates, 1971a, 1971b). These documents were later Americanized and published as a three-volume technical report, AFHRL-TR-71-53 (Folley et al,, 1971, 1971b; Joyce, Folley, & Elliott, 1971). These Americanized documents have since been carefully updated and published by AFHRL as another three-volume technical report, AFHRL-TR-73-43 (Joyce et al., 1973a, 1973b, 1973c).

All of the Vietnamization efforts are listed in Table F2 including these guidance documents and the evaluation of the UH-1H JPA. While the specification and guidance document were being developed, additional JPA were being developed on a sole-source basis for two aircraft – the C-123K and the CH-47A. The other follow-on efforts (with the exception of the Seek Point project) were procured on a multisource basis. Table F2 indicates the time frame of each of the Vietnamization efforts, the types of JPA included, and the levels of maintenance covered. All of these aids produced for Vietnamization were in a two-language format.

Table F2. **Information Concerning Vietnamese Air Force (VNAF) Job Performance Aids (JPA) Efforts**

Project 1127 Tasks	Title of Effort	Types of JPA			Level of Maintenance			Start	Complete	Contractor
		FPJPA Non-Trouble-Shooting	FPJPA Trouble-Shooting	MDC Trouble-Shooting	Organizational	Intermediate	Depot			
1, 2, 4, 9	UH-1H JPA	X	X	X	X			Jan 70	Oct 70	XYZYX[a]
5	C-123K JPA	X	X		X			Oct 70	Apr 71	XYZYX
7	CH-47A JPA	X	X		X			Oct 70	Mar 71	XYZYX
3	Specification (Mil J 83302)	X	X	X	X			Sep 70	Dec 70	ASA[b]
3	Handbook for JPA Developers	X	X	X	X			Sep 70	Jan 71	ASA
10	Handbook for JPA Managers	X	X	X	X			May 71	Aug 71	ASA
13	UH-1H JPA Evaluation	X	X	X	X			May 71	Oct 71 (Feb 72)	Matrix[c]
14	C-7A JPA	X	X		X			Oct 71	Aug 72	Westinghouse[d]
15	J85-17A, 17 Jet Engine JPA	X	X		X			Oct 71	Aug 72	Kentron[e]
16	T53-L-13 Jet Engine JPA	X	X		X			Oct 71	Aug 72	Kentron
17	T55-L-13 Jet Engine JPA	X	X		X			Oct 71	Aug 72	Kentron
18	R-8 Refueling Vehicle JPA	X	X		X	X		Oct 71	Aug 72	Westinghouse
19	530 B Fire Truck JPA	X	X		X	X		Oct 71	Aug 72	Westinghouse
20	O-11A Fire Truck JPA	X	X		X	X		Oct 71	Aug 72	Westinghouse
ESD Project	Seek Point	X	X		X	X	X	Sep 71	May 73	ASA

[a]XYZYX – The XYZYX Information Corp., Canoga Park, CA.

[b]ASA – Applied Science Associates, Inc., Valencia, PA.

[c]Matrix – URS/Matrix Research Company, Falls Church, VA.

[d]Westinghouse – Westinghouse Corp., Hunt Valley, MD.

[e]Kentron – Kentron Hawaii, Dallas, TX.

The JPA developed for the UH-1H aircraft, like those developed for the C-123K and CH-47A aircraft, were developed without the benefit of the structured TI&A required by specification Mil-J-83302. A formal evaluation was made of only the UH-1H aids (see Shriver & Foley, 1975). The lessons learned from the various procurements listed in Table F2 coupled with those learned from the evaluation of the UH-1H aids contributed a great deal to the evolution of the FPJPA technology.

Lessons Learned from Evaluation of the UH-1H Aids

1. The development and evaluation of the UH-1H JPA strongly indicated that a traditional format specification such as Mil-M-38800 would not produce complete and effective JPA.

2. A systematic task identification procedure is required to insure that a step-by-step procedure is developed and available for every hardware task for which the maintenance technician is responsible.

3. Technically correct step-by-step directions in standard language, keyed to locator pictorials, are necessary but not sufficient attributes of task directions. To insure correct performance of each task, the directions and accompanying pictorials for each task must supply all the necessary information and cues required by members of the target population to perform the task (Shriver, 1975; Shriver & Foley, 1975).

4. A systematic analysis is required for each task to insure the presence of all the necessary information as well as to identify most of the cues required for the preparation of effective draft directions and accompanying pictorial locators. Such draft directions must be given a "hands on" hardware validation by the contractor to insure that all necessary cues are present and that a typical maintainer can perform the tasks using the directions. (In this regard, the more careful the original analysis of each task, the fewer the modifications required for its directions during validation.)

An Expanded Specification

The legal requirement and guidance for such task identification and analysis (TI&A) of identified tasks was provided for the multisource procurements of JPA by the specification (Mil-J-83302) and the companion guidance handbooks (Applied Science Associates, 1971a, 1971b). These multisource procurements included aids for the C-7A aircraft, three jet engines, two fire trucks, and a refueling vehicle (indicated in Table F2). However, the existence and callout of the specification in the procurement contract is a necessary but not sufficient action for the successful development of JPA. The development of the sub-products of TI&A for evaluation and acceptance by the Air Force was a new experience for both contractor and Air Force procurement personnel.

Key Lessons Learned from Application of Expanded Specification

1. The JPA technology as structured in Mil-J-83302 is a new technology requiring substantial changes in skills and attitudes of technical writers and their associated management personnel—both contractor and Air Force. The application of this specification and its accompanying guidance to these multisource procurements confirmed the requirement for DOD capability for evaluating and accepting the TI&A products, for insuring the use of these products as criteria during the development of the aids, and for conducting the "hands on" verification of the completed JPA.

2. Since most of these actions were new to both Air Force and contractor personnel, these capabilities were developed by expensive "cut and try" procedures. No doubt, the most effective action for developing the necessary skills and attitudes would be appropriate training programs which would provide supervised practice of the skills required. Such training programs also would help develop the necessary attitudes toward this unfamiliar technology.

3. The Vietnamization project had no formal mechanism for effectively utilizing the "know how" of the R&D community.

APPENDIX G: SUMMARY OF AIR FORCE HUMAN RESOURCES LABORATORY (AFHRL) CONTROLLED COMPARATIVE STUDY CONCERNING THE EFFECTIVENESS OF FPJPA TECHNOLOGY FOR TS TASKS

This study generated comparative data concerning Fully Proceduralized Troubleshooting Aids (FPTA), enriched Logic Tree Troubleshooting Aids (LTTA), traditional maintenance manuals (TMM) (called Technical Orders (TO) by the Air Force).

The detailed results are reported in AFHRL-TR-76-74(I) (Potter & Thomas, 1976). Table G1 indicates success in terms of percentage of troubles, identified by each experience level using each type of maintenance data. All of the subjects of this study had high electronic aptitudes (80 percentile and above).

Table G1. **Comparison of FPTA, LTTA, and TO in Terms of Percentage of Troubles Found**

Experience of Subjects	Maintenance Level	Type of Data: FPTA O	FPTA I	LTTA O	LTTA I**	TO O	TO I
Inexperienced	Organizational (O)	88.9		77.8		*	
	Intermediate (I)		88.8		60.6		*
Through 6 months	O	100		100		100	
	I		95.4		89.4		60.6
Over 6 months	O	95.8		95.8		100	
	I		95.4		87.8		78.8

*No data collected.

**I level LTTA did not contain location pictorials.

Table G2 indicates the excessive number of spare parts utilized in the process of finding these faults. These data are expressed in terms of the average number of unnecessary spare parts used per trouble. In this table the results for the two experienced groups are combined.

Table G2. **Comparison of FPTA, LTTA, and TO in Terms of Spare Parts Used**

Experience of Subjects	Maintenance Level	Types of Data: FPTA O	FPTA I	LTTA O	LTTA I	TO O	TO I
Inexperienced	O	.77		1.00			
	I		1.44		2.22		
Experience	O	.13		.25		.53	
	I		1.03		.94		1.86

Table G3 indicates the developmental cost in dollars of the FPTA and LTTA for both O and I maintenance for the AN/APN-147 and AN/ASN-35. The FPTA was more expensive to develop than LTTA. (It should be recalled that the LTTA for I maintenance did not contain pictorial locators which, if added, would no doubt have increased the cost).

Table G3. **Comparison of Cost Experienced in Dollars for the Development of FPTA and LTTA for the AN/APN-147 and AN/ASN-35**

Maintenance Level	FPTA	LTTA	Difference
Organization (O)	14,451	7,593	6,858
Intermediate (I)	164,680	111,076	53,604
Total	179,131	118,669	60,462

When the results presented in these three tables are considered in terms of what type of troubleshooting aids are most cost effective *for the type of experienced personnel now assigned to the Air Force*, one can easily conclude that the LTTA is the most cost effective in terms of TO development dollars.

1. At the O level of maintenance, experienced personnel did quite well with TO, LTTA, and FPTA.

2. At the I level, both LTTA and FPTA were far superior to TO.

3. At the I level, FPTA was somewhat more effective than LTTA in terms of troubles found. And in terms of unnecessary spare parts used, both were about the same with the slight difference favoring LTTA. But in terms of cost, the FPTA was $53,604 (or 48 percent) more costly to develop.

At least for the present, the Air Force Logistics Command (AFLC) technical data establishment has decided in favor of the LTTA. *But such a decision must be based on tacit assumptions that the personnel using these aids will always have the high aptitudes, the long training times, and the substantial experience advantages now enjoyed by the Air Force.*

However, when the results presented in these tables together with other available data are considered in terms of potential for more effective utilization of first enlistment personnel, *one can conclude that a large amount of the potential for effecting substantial future personnel savings may have been lost by the decision in favor of LTTA.* The following results obtained from inexperienced personnel indicate that such personnel performed much better with FPTA.

1. Inexperienced subjects found more O and I level troubles when using FPTA than when using LTTA – at the O level, 11.1 percent more (88.9 – 77.8), and at the I level, 28.2 percent more (88.8 – 60.6). (Inexperienced subjects did not use TO.)

2. Inexperienced subjects used fewer unnecessary spare parts per trouble when using FPTA than when using LTTA for both levels of maintenance, i.e., .23 more at the O level and .78 more I level.

These data would indicate that by using FPTA, the Air Force could get immediate utilization of newly assigned personnel either from school or from assignments on other hardware. This would greatly reduce the requirement for expensive on-the-job training (OJT) or cross-training. It would also provide a more rapid buildup potential in case of national emergencies. When viewed from the potential savings in personnel costs and potential for rapid personnel buildup points of views, the relatively small immediate savings of $58,207 (from Table G3, $118,669 – $60,462) could be very expensive in the long run. Also, the use of LTTA in lieu of FPTA could greatly reduce the potential savings from well designed FPJPA/task oriented training trade-offs.

Within the next 10 years the number of young people in the United States population is expected to decrease rapidly. If for no other reason, it is most probable that DOD will have to lower its aptitude requirements for entry into maintenance jobs. Although the 1967 advanced development plan called for consideration of medium aptitude personnel, it was not included in the study reported here. But a previous exploratory development study indicated that inexperienced, average aptitude subjects using FPTA found about 10 percent fewer troubles on the first attempt than did high aptitude subjects. Projecting this

difference on the data presented in Table G1, one could expect average aptitude subjects to find about 80 percent of the troubles using FPJPA for both O and I levels. If FPJPA were developed for average aptitude subjects as the target population, this percentage could probably be increased. In any case, FPTA would be more effective than LTTA, for maximum utilization of average aptitude (40 to 70 percentile) personnel.

In defense of the Air Force TO establishments, currently a prime criterion for their performance is economy in TO production. The TO people get no credit, financial or otherwise, for saving personnel dollars. And there is no mechanism for transferring personnel money to TO production.

APPENDIX H: SUMMARY OF NAVAL AIR DEVELOPMENT CENTER (NADC) FPJPA/TOT TRADE-OFF STUDY (Theisen et al., 1978)

Description and Results

1. Starting in 1972 the Human Engineering Division of the Naval Air Development Center (NADC), Warminister, Pennsylvania, supported a FPJPA/TOT trade-off effort. Historically, this effort had its genesis in the AFHRL FPJPA/TOT trade-off demonstration which was conducted at Altus AFB, Oklahoma in early 1972 (see Mullen & Joyce, 1974). Whereas the Altus effort was only a demonstration, the Navy effort was planned as a full scale controlled study to determine the relative effectiveness of the combined FPJPA and TOT technologies with respect to traditional theory based training and TMM. Unfortunately, the controlled comparative aspects of this plan were never completed. Nevertheless, FPJPA for O and I level maintenance of the AN/AQA-7 Sonar Recorder Group, as well as matching TOT packages (one for O level technicians and one for I level technicians), were developed. And hard data as to their effectiveness were obtained.

2. The job aids for the AN/AQA-7 Sonar Recorder Group developed for this effort reflected the vintage of FPJPA technology found in the three volume technical report AFHRL-TR-71-53 (Folley et al., 1971a, 1971b; Joyce et al., 1971). This was a more advanced vintage of developmental technology than reflected by the FPJPA used in the Altus demonstration, which was developed without the benefit of such structured guidance. The aids used at Altus were limited to TS, whereas the aids developed for this effort covered non-TS tasks as well. However, the author feels that the AN/AQA-7 developmental effort omitted some very important aspects of the specification and guidance documents found in AFHRL-TR-71-53. These documents require that all the formal products of the task identification and analyses (TI&A) of identified tasks be reviewed and accepted by the procuring agency, in this case NADC. They, also, require that the procuring agency ensure that these products are utilized as content criteria during the development of the actual FPJPA. The only IT&A products which received such treatment were the troubleshooting action trees. In addition, due to funding and scheduling problems all FPJPA did not receive the required contractor validation and the government verification. Only those FPJPA used for the experimental tryout problems received such treatment.

3. As to the TOT packages, they were more complete than those developed for the Altus demonstration. For those subjects assigned to organizational (O) maintenance a 13 week TOT package was developed to prepare average aptitude personnel (approximately 40 to 50 percentile) to perform O level maintenance on the AN/AQA-7 Sonar Recorder Group of the S2-G aircraft using FPJPA. A 16 week TOT package was developed to prepare the same range of average aptitude personnel to perform I level maintenance tasks on the same equipment using FPJPA. The contract monitor has indicated that these TOT packages were of good quality. However since these packages arrived 4 weeks after training started, the subjects did not obtain the full advantage of their potential.

4. Traditionally, the AN/AQA System has been maintained by "A" school graduates using TMM. The entry aptitude for "A" school is 84 percentile and above. The appropriate "A" school program was 22 weeks in length and was theory based. Students selected for O level maintenance received 2 additional weeks of AN/AQA specific training making a total of 24 weeks. Students selected for I level maintenance received 14 additional weeks of system specific training making a total of 36 weeks. So the TOT package for O level training was 11 weeks shorter than conventional training (a 46 percent savings in training time) and the I level package was 20 weeks shorter than conventional training (a 56 percent savings in training time).

5. The original plan for the conduct of TOT included the following assumptions: (a) students would arrive in four groups of 10 each approximately 1 to 2 weeks apart, (b) there would be four instructors, two to teach I level maintenance program and two to teach O level maintenance program, (c) two AQA-7 systems and AQM-18 test benches could be made available for the exclusive use of the project, and (d)

access to S2G aircraft (with operating AQA-7s) could be obtained. Unfortunately, none of these conditions were met, the students arrived early and all within a single 10-day period, only three instructors could be recruited, only one AQA-7 and AQM-18 could be provided, and access to S2G aircraft was limited due to heavy flight commitments of the operational forces. Finally, as mentioned previously, the TOT training materials were delivered approximately 1 month late and not properly collated.

After delivery and assembly of the training materials, the 41 trainees were divided into three sections; two sections of 13 trainees each were designated for "I" level training, and one section of 15 trainees was designated for "O" level training. Since only one AQA-7 system and one AQM-18 test bench could be made available for instruction, it was decided to establish a 24-hour teaching day consisting of three 8-hour sessions. Sessions were scheduled Monday through Thursday to conform with the normal NAS Cecil Field, Florida, work week. Arrangements were made with the Aviation Intermediate Maintenance Department of NAS, Cecil Field to obtain priority repairs on the AQA-7 components used in training. Despite this excellent support, many training hours were irretrievably lost due to equipment being inoperative for maintenance. Consequently, the trainees received much less practice than planned because of the larger than planned class size and the shortage of equipment.

6. The evaluation of the subjects sought to provide a realistic and practicable work setting with representative maintenance problems. Since the data collection had to be accomplished in 4 weeks, only five problems could be scheduled for each O level subject and only four for each I level subject. However, the problems selected are considered representative. The results are displayed in Table H1.

Table H1. **Task Success of Medium Aptitude Subjects (40–50 Percentile) Using FPJPA**

Levels of Maintenance	Problem Identification	Non-Ts	TS	Percent of Problems Successfully Completed
O Level Problems: (12 subjects)	19A2		X	90.5
	20A–1		X	91.1
	1A1		X	97.1
	4A2		X	57.5[a]
	FMS#2		X	97.0
Composite of O level:				86.6
I Level Problems: (23 subjects)	6A4	X	X	84.4
	PP6306		X	93.7
	4A2	X(Align)		68.2[a]
	11A3	X(Align)		82.5
Composite of I Level				82.5
Composite of O and I Levels				84.1

[a]Problem required each subject to use the dual beam feature of the oscilloscope. Subjects had received no training concerning this feature of the scope.

These results are only slightly lower than those reported for the AFHRL advanced development study by Potter and Thomas (1976). In the Potter and Thomas study, which considered only troubleshooting problems, the inexperienced subjects isolated 89 percent of both O and I level troubles (see Table F1, Appendix F). When the O and I troubleshooting problems are considered, Table G1, a composite percentage of about 88 percent is obtained (87.7). It should be noted that the Potter and Thomas study utilized high aptitude subjects (80 percentile and above) who had completed 36 weeks of conventional theory based training whereas this study utilized only average aptitude subjects.

7. The subjects of this study, as well as those in the Potter and Thomas (1976) study and the Altus demonstration (Mullen & Joyce, 1974), displayed weaknesses in their ability to use key test equipment, especially the oscilloscope. The percentages of troubles successfully found, although impressive, would no doubt have been higher if subjects had possessed high proficiency in the use of their test equipment. (There is also substantial evidence that this is a common weakness of many DOD experienced maintenance technicians (Foley, 1969).)

Such lack of test equipment proficiency indicates that the subjects had received insufficient "hands on" practice in the use of appropriate test equipment functions. In the Altus effort (Mullens & Joyce, 1974), this weakness was attributed to a lack of sufficient practice frames in the training package. As a result, the Altus report (Mullen & Joyce, 1974) recommended that future TOT packages contain more practice frames. Since the TOT packages for this study arrived late, most subjects had insufficient time for completing their TOT packages. It can be assumed that subjects would have successfully completed even more tasks if they could have had the full advantage of their TOT packages.

However, one important omission was found in both the O and I level TOT packages. No training was provided on the dual trace function of the oscilloscope. The relatively low percentages of successful completions for the O level task 4A2 and the I level task 4A2 (Table H1) were the direct result of these inadvertent omissions.

8. This project did demonstrate that combining the FPJPA and TOT technologies was feasible and that such a trade-off would reduce initial training time for first term maintenance personnel. In spite of all the difficulties previously mentioned, the performances of the medium aptitude subjects of this study were impressive. Their performances were as good or better than those of high aptitude, conventionally trained subjects in other studies. All of the mentioned difficulties are correctable and their correction would result in still higher levels of performance.

Lessons Learned

1. The study reiterates findings of other FPJPA studies that the effectiveness of quality FPJPA can be substantially degraded by users' inability to use their test equipments proficiently. In all future applications of FPJPA, appropriate actions must be taken to assure that FPJPA users can employ their test equipment accurately.

2. Although in-depth "hands on" verification procedures were only applied to FPJPA for those tasks used in the evaluation, a number of weaknesses of omission and commission were identified. This verification reiterates the requirement for the review and acceptance of all products of TI&A (not just TS trees) by the procuring agency. The procuring agency must also ensure that the appropriate TI&A products are used as criteria for content control during FPJPA development. And these assessment activities are necessary for quality FPJPA even if the contractor has highly experienced personnel in FPJPA development. (These necessary activities require that the procuring activity have personnel with the necessary skills.) As stated in the body of this report, as well as in Appendix B, these activities together with validation and verification of the final FPJPA are all part of the FPJPA technology and are necessary activities for ensuring the production of quality FPJPA.

3. During the development of the FPJPA for the AN/AQA-7 systems, its I level maintenance concept changed. Originally I level maintenance was responsible for only identifying faulty integrated circuit cards, all within card repair being assigned to depot maintenance. This within card responsibility was transferred to the I level, approximately tripling the number of I level trouble signatures for FPJPA, TS coverage. Because of time and R&D funding limitations, FPJPA for these additional signatures were not developed for this project. This is an example of the domino effect on maintenance guidance and/or training which can be produced by a change in the maintenance concept of a system. When FPJPA and TOT are involved, the results are immediately apparent, because of the stringent contant controls of these technologies. Although the effects of such a drastic change in maintenance concepts are not as immediately apparent with traditional theory based training and TMM, the results no doubt are hidden in increased destruction of parts and costly secondary damage to hardware–in this case to expensive integrated circuit cards.

APPENDIX I: ARMY APPLICATIONS OF IMG&I AND TOT TECHNOLOGIES

Although the Army was not directly involved in much of the R&D effort concerning either improved maintenance instructions or TOT during the last decade, it is now the most active service in attempting to exploit these technologies. This exploitation has had several stages. The *first* was a contract effort with KINTON, Inc. of Alexandria, Virginia, which resulted in a review of all the *new* concepts and technologies concerning improved maintenance instructions and TOT; the development of draft specifications for job performance manuals (JPM) and job performance guides (Draft Mil-M-632XX (TM), Part I); and the development of an accompanying specification for TOT (Draft Mil-M-632XX (TM), Part II).

The specifications called for a TI&A (called "front end" analysis) similar to that found in the Air Force Vietnamization specification Mil-J-83302 and AFHRL-TR-73-43(I), but the in-process review requirements of the products of TI&A for Mil-M-632XX were not as stringent. Directions for the non-TS tasks reflected the FPJPA technology; however, the verb list furnished in the Mil-M-632XX omitted the precise definitions found in Mil-J-83302. Information and directions for TS called for modification of the FORECAST TS aids rather than the FPJPA technology. The major modification to the FORECAST aids was the addition of pictorial locators for test points. No guidance documents, such as those found in AFHRL-TR-73-43 (Volumes II and III; Joyce et al., 1973b, 1973c), were furnished with draft Mil-M-632XX. Although in the author's opinion, the FORECAST TS aids are not as effective for first enlistment personnel as is the FPJPA technology for TS, there are substantial hard data (Shriver et al., 1964) which indicate FORECAST TS aids to be effective with such personnel. In fact, all the major technical data and training requirements of draft Mil-M-632XX (Parts I and II) are supported by substantial hard data. However, the FPJPA technology aspects of the requirements were somewhat "watered down" by the less stringent in-process review requirements, the lack of guidance documents, and the removal of precise definitions from the approved verb lists.

This KINTON effort produced a Technical Memorandum 29-75 (Shriver & Hart, 1975), which discusses the development of the Mil-M-632XX specifications. It also makes some predictions as to the savings to be expected from the application of the technologies represented by these specifications in terms of shorter initial training *for* and more effective operation and maintenance performance *by* first enlistment personnel.

The *second* stage of the Army program consists of the application of Mil-M-632XX, with the exception of the TS aids, to three systems: the Tank Turret, XM 1 Tank, and TACFIRE (Tactical Fire Direction System). For these systems, LTTAs of uncontrolled enrichment are replacing the recommended FORECAST TS aids. There are no hard data which indicate the amount of LTTA enrichment required to be effective for first enlistment personnel.

The *third* stage of this program has been the replacement of draft Mil-M-632XX by a series of specifications for future ITDT projects, including Mil-M-63035 (TM), -63036 (TM), -63037 (TM), -63038 (TM) and companion handbooks, and -63040 (TM). The Mil-M-63035 (TM) retains the requirement for "front end" analysis. Mil-M-60340 (TM) replaces part II of draft Mil-M-632XX concerning TOT. The remainder of the series provides for a number of technical data optimums. The effectiveness of none of these optimums is supported by hard data. The JPM for non-TS tasks from the FPJPA technology has been replaced by the "new look" manual which contains directions supported by pictorials. However, the content of these directions is not in standard language. Two formats of LTTA are provided, one with pictorial locators and one without. But other aspects of enrichment are uncontrolled and can vary from application to application.

The *fourth* stage of this program consists of the application of this modified ITDT including "new look" and LTTA to a number of systems including the TOW/DRAGON (anti tank missile), the Advanced Attack Helicopter (AH-64), the M939(5T) (5 ton truck), and M204 Machine Gun. Since these modified ITDT applications contain so many untested and watered down components, their effectiveness for first enlisted personnel will probably be below those projected in Technical Memorandum 29-75 (Shriver & Hart, 1975), as well as below what could be expected from a full application of the FPJPA technology coupled with TOT.

The *fifth* stage of this Army program calls for a revision of the ITDT specifications. Such a revision will hopefully correct some of these shortcomings of the current ITDT and thus increase their potential effectiveness.

APPENDIX J: AIR FORCE APPLICATIONS OF FPJPA TECHNOLOGY

Most of the Air Force maintenance manual efforts reflecting the FPJPA technology have been developed under Mil-M-38800A which reflects only the format aspects and not the content control aspects of the technology provided by task identification and analysis (TI&A). (TI&A is sometimes called "front end" analysis.) Such applications have been further limited to the O level of maintenance and to non-TS tasks. However, the maintenance manual establishment of AFLC has taken positive action to include the TI&A aspects of the technology in future applications. One expected outcome of the recent AFLC Request for Personnel Research (RPR) 77-19, mentioned previously, calls for the development by AFHRL of a specification for maintenance task analysis for both non-TS as well as TS tasks and for both I and O levels of maintenance. Another promising feature of this action is that the developers of the technology are being given an active role in its implementation.

Of the past Air Force maintenance manual improvement efforts, the development of the improved manuals for the C-141 aircraft most nearly reflects the full scope of the FPJPA technology. This development applied only to the O level of maitnenance. The requirements for the TI&A, as well as in-process reviews of the TI&A and resulting manual development, were included in the statement of work of the contract. The aids called Job Guide Manuals (JGMs) for the non-TS tasks were formatted as specified in Mil-M-38800A.

The C-141 contract called for the development of LTTA for TS tasks. The troubleshooting or logic trees were carefully developed by the contractor based on hardware analyses which identified all of the trouble signatures. These troubleshooting trees were then reviewed for their adequacy by a group of Air Force maintenance specialists. The contractor provided a high degree of enrichment at each decision point of these trees, in terms of directions and information. Nouns mentioned in the directions were referenced to locator pictorials. The developmental process, as well as the enrichment added to the basic logic trees, was very similar to that called for by the FPJPA technology for TS tasks.

The other Air Force implementations have only been partial applications of the technology, limited to its format aspects as specified by Mil-M-38800A. JGMs in this format have been developed for non-TS, organizational maintenance tasks to replace existing traditional manuals for the B-52, KC-135, and the F-106 (partial). Plans are to update other systems as funds become available. Such JGMs were developed as part of the original hardware development for the F-5E and the A-10. They are being developed for the F-16 and are planned for the Advanced Medium STOL Transport (AMST), as well as for various other subsystems for the Air Force Avionics Systems Division (ASD) and Electronics Systems Division (ESD). JGMs also were planned for the B-1.

As to support of TS tasks at O level of maintenance, the Mil-M-38800A authorizes the use of LTTA or symptom-cause charts but no guidance is given either as to their content or format. As stated previously, symptom-cause charts provide very limited TS guidance. The organizational maintenance manuals for the A-10 include JGM for non-TS tasks but symptom-cause charts for TS tasks.

APPENDIX K: OFFICE PRODUCTS DIVISION OF IBM: INTEGRATED APPLICATIONS OF IMG&I/TOT TRADE-OFF AND JOB TASK PERFORMANCE TESTS (JTPT)

The Office Products Division of IBM has an impressive integrated system of personnel utilization. It is an excellent example of what properly applied human engineering could do for any maintenance organization. The important thing for DOD to emulate is the process and its organization. The exact format of this IBM personnel utilization system was designed to meet the needs of the Office Products Division, which of course, are somewhat different from those of DOD. One important aspect of the IBM system which could be emulated by DOD is that success in all training and job advancement is based primarily on ability to perform job tasks as measured by task performance tests. Some other important aspects of this personnel utilization system include:

1. The responsibility for the maintenance manual development, service ability of equipment, aptitude test development, formal training development and execution, field training packages, and performance assessment center are under one directorate–the Director of Technical Operations.

2. The selection, hiring, and initial training of maintenance personnel has been decentralized and is the responsibility of the field service managers. However, the development and control of the selection tests, as well as the training packages are the direct responsibility of the training establishment under the Director of Technical Operations.

3. The initial training packages are of the programmed instruction variety and provide step-by-step exercises for "hands on" practice of key maintenance tasks of simple IBM office equipment, such as typewriters and dictation equipment (IPE). Successful completion of this training program is dependent on the Trainee's demonstrated ability to perform the key maintenance tasks of these equipments.

4. Graduates of the entry training are subject to an extensive battery of job task performance tests given in a job qualification center. From 1969 until March of 1977, *all* graduates were required to visit an assessment center upon completion of entry training. An average of 1,000 trainees per year were evaluated during this time period. This performance testing program has had two objectives – to ascertain the quality of entry training and to develop a bank of performance data for the development and validation of the selection test battery. (This test battery was validated in 1973.) Since March 1977, a modified random sample of about 16 percent of the entry personnel have been required to visit the assessment center for quality control purposes.

5. Once the employee's entry field training is completed, very careful records are kept concerning the subsequent job success as measured by the faults, the number of spare parts, and the time required for each maintenance action. Selection for training on advanced systems is based on job success. Training programs for advanced systems are both centralized and decentralized.

6. The field training packages for initial or advanced training, as well as the centralized training for advanced systems, are job task oriented. The training materials look very much like job guide manuals. Over the years, if the task directions found in the maintenance manuals were deemed adequate, they were used for training. If not, task directions were rewritten for training, and the inadequate directions in the maintenance manuals were changed accordingly.

7. This IBM integrated personnel utilization system including training and maintenance manuals has been the result of years of such "cut and try" efforts rather than on a formal TI&A process. This is possible when the number of types of equipment is relatively small, when all of the equipment is made by one manufacturer (and as a result, has many common elements), when the integration is directed by one manager who has and listens to excellent human factors advice, and when the reaction time for implementation of changes is extremely short.

8. Most maintenance directions for non-TS tasks are given in step-by-step format supported by pictorial locators. They do not use the same type of standard language, characteristic of the FPJPA technology. However, they do use a simplified vocabulary or "common English" so that the same training materials can be used in conjunction with IBM's world trade. There are two types of TS data; one is very similar to the format called for by AFHRL fully proceduralized aids, and the other is a flow type aid similar to that used in FORECAST.

9. IBM has a functional and functioning rotation policy for managers who are expected to have staff experience in field maintenance, technical support, and training. All of the managers, including vice preseidents, started their careers with IBM as maintenance technicians.

10. This whole integrated personnel utilization system is the result of a felt need on the part of IBM's forward looking, and maintenance oriented, management in the middle 1960s. IBM was going to expand the number and complexity of its office products. It was realized that to do this profitably their maintenance organization had to be expanded in size and capability with a minimum of manhours spend off the job in training. (Even with this expanded number of systems, many single Air Force Specialty Codes encompass a greater number of systems, which reflect the design eccentricities of many manufacturers.)

APPENDIX L: BELL SYSTEM APPLICATIONS OF FPJPA TECHNOLOGY

The Bell System uses TI&A extensively for solving operator and maintenance personnel and training problems. The Bell System is somewhat similar to DOD in that it is large and diverse with many more-or-less independent companies, each with its own management. It is different from DOD in that its maintenance technicians (craftsmen) have, on the average, much longer careers, and the tasks of their jobs are not as diverse—Bell System having only one source of hardware i.e., Western Electric.

A reflection of the strong interest in TI&A by Bell System was its sponsorship of a "Conference on Uses of Task Analysis in the Bell System" in October 1972 (Bell System, 1972). Approximately 40 papers were presented concerning the uses of TI&A for Job Design and Restructuring, Personnel Research and Administration, Basic Education, Design of Systems, Design of Training and Job Performance Aids. The Bell System's approaches to TI&A have the same foundation and are very similar to those of the Advanced Systems Division (AS) of AFHRL. The Bell users of TI&A recognize Dr. Robert B. Miller, who gave an invited address at the conference, as the father of modern task analysis. Dr. Miller accomplished his work in this area at the American Institutes for Research (AIR) under Air Force contracts in the 1950's. The conference proceedings also indicate that the Bell System has borrowed heavily from Air Force reports in its development of Task-Oriented Plant Practices (TOPP).

Bell has also utilized both TOT and JPA technologies. An important input to the Bell System ongoing application of the JPA technology was an internal guide for JPA development by Applied Science Associates (ASA) of Valencia, Pennsylvania. This was followed by a training program based on this guide, given to Bell personnel at Bell Laboratories by ASA personnel. With some modifications, this training is now one of the regular and popular courses given by Bell Laboratory at Piscatway, New Jersey for Bell System managers, the idea being to greatly reduce or eliminate much costly training by using good job instructions.

However, Bell System does not have as formal and precise trade-offs of TOT and JPA as do some other organizations. The applications made by Bell System are for solving specific problems. Some of the individual Bell Systems are larger than IBM Office Products Division and little information seems to be available concerning specific applications by individual Bell Systems. Another version of this Bell course is given by New England Bell at Marlborough, Massachusetts.

APPENDIX M: ARMCO APPLICATIONS OF IMG&I AND TOT TECHNOLOGIES

In the late 1960's, Armco installed electronic controls on its rolling mills in place of previously installed electro-mechanical controls. The on-board maintenance technicians were having considerable difficulty maintaining these electronic controls. This Armco experience is reported in the 6 December 1976 issue of Iron Age (Snodgrass, 1976). The problem and its solution contained the following features.

1. Armco management had foreseen that their electro-mechanical maintenance technicians would not have the necessary skills for maintaining the electronic controls and had attempted to solve this deficiency in a traditional manner. For several years an apprentice program was attempted. This program included junior-college level theory training together with an OJT program conducted for the Armco plant at Butler, Pennsylvania. This approach was tried for more than 3 years. But the products of this training program could not maintain the electronic controls in a satisfactory manner. Finally the Armco management engaged ASA to help solve the problem.

2. Based on TI&A, ASA developed a JPA/TOT trade-off program. Three types of maintenance guidance were developed: (a) FPJPA TS aids without pictorial locators. (The maintenance technicians already knew the geography of the equipment); (b) a data flow chart type of TS aid very similar to FORECAST aids; and (c) a preventive maintenance checkout aid indicating normal readings at all check points in the equipment. A 1-week programmed instruction package was developed providing "hands on" practice on the use of test equipment and on troubleshooting, making use of the improved maintenance guidance.

3. ASA provided a training program for Armco instructors on how to conduct such a trade-off program. Armco instructors have been using the ASA materials to train their own maintenance technicians on an ongoing basis using one instructor for two students. Armco has provided actual electronic control equipment for the required "hands on" practice.

4. The program produced immediate improvements in the performance of maintenance tasks. In addition, the use of the preventive maintenance checkout aids made it possible to predict many component failures in advance, so that they could be replaced during scheduled downtime, thus preventing costly unscheduled breakdowns.

5. Armco has developed an in-house capability for developing the data flow charts aids for other maintenance applications.

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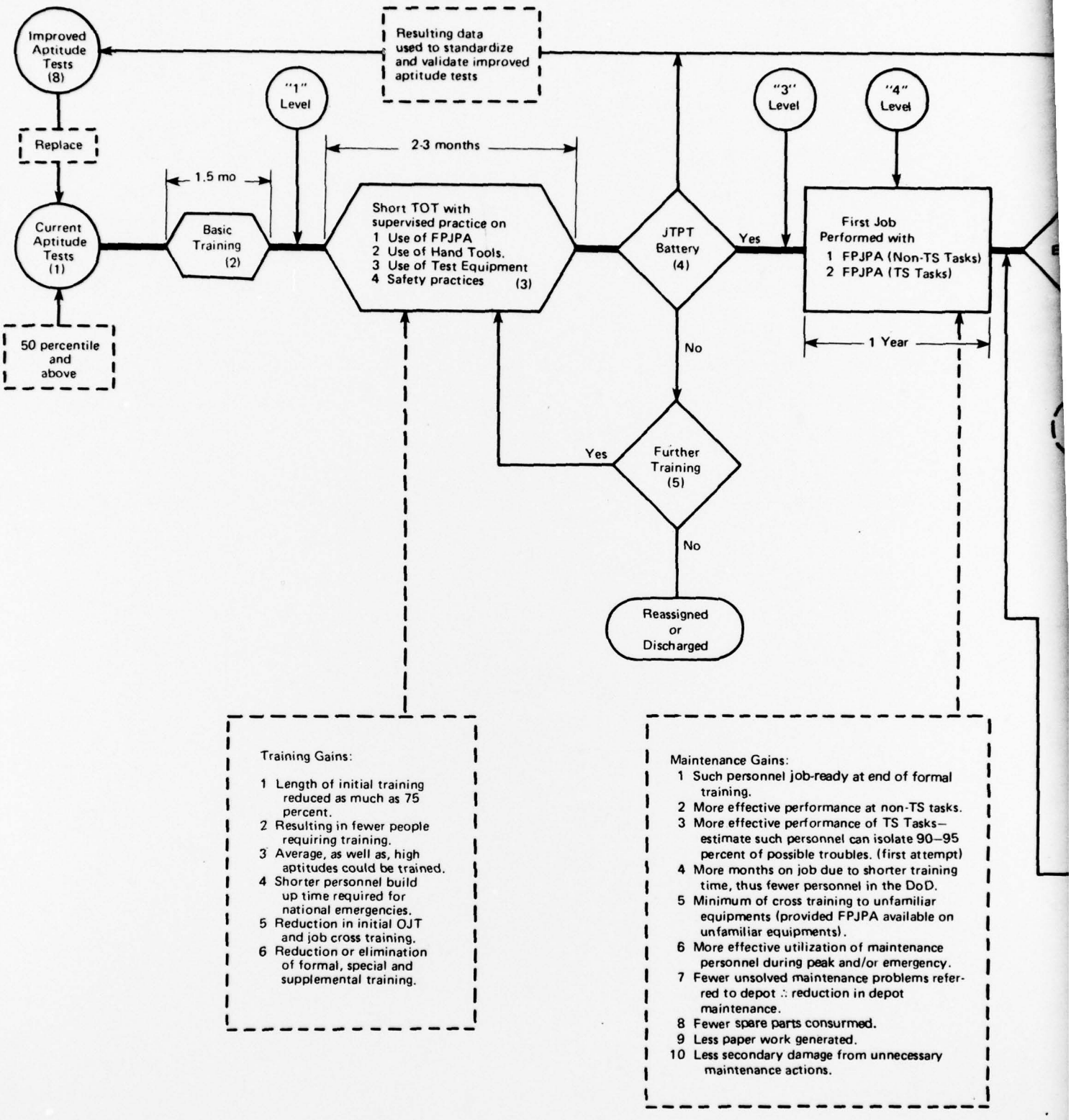
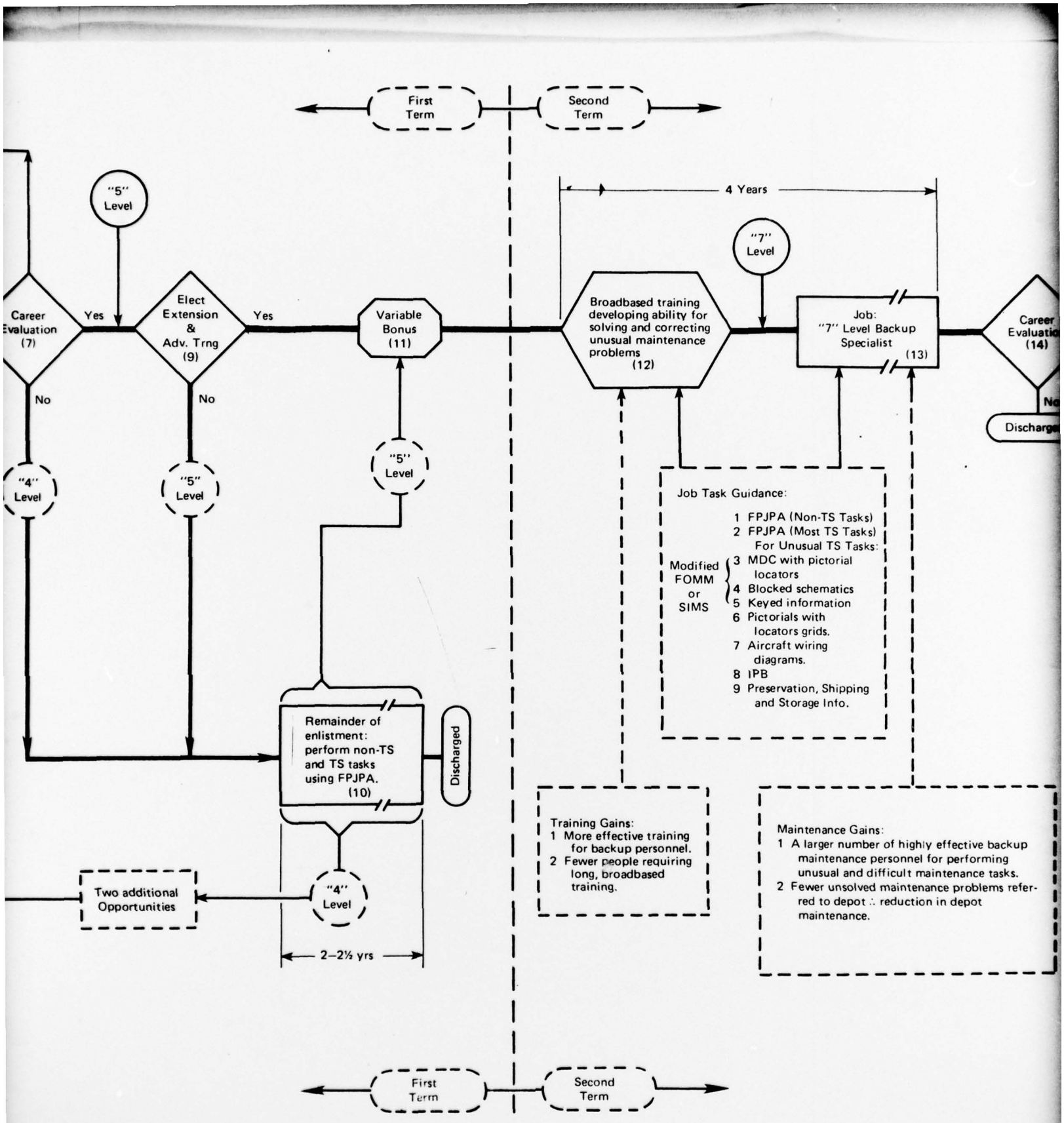
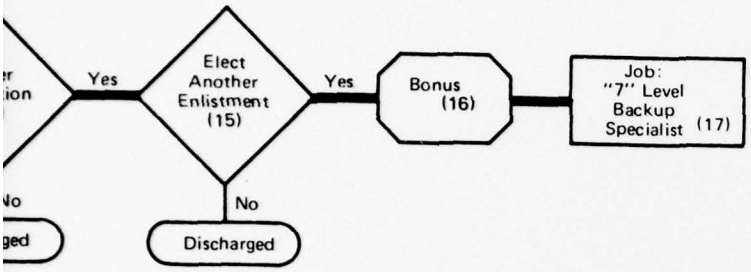


Figure 2. Annotated flow diagram portr



traying a model for maximizing benefits of FPJPA, SIMS and TOT technologies.


Yes
Elect Another Enlistment (15)
Yes
Bonus (16)
Job: "7" Level Backup Specialist (17)
No
Discharged